AD-A056 102 MITRE CORP BEDFORD MASS F/G 15/5
AFSATCOM LIFE CYCLE COST MODEL,(U)
JUN 78 J H JAMES, W M STEIN F19628-77-C-0001
UNCLASSIFIED MTR-3057 ESD-TR-78-114 NL

1 OF 2
AD
A056 102

AD A056102

ESD-TR-78-144

LEVEL II

MTR-3057

AFSATCOM LIFE CYCLE COST MODEL

BY J. H. JAMES AND W. M. STEIN

JUNE 1978

AD No.
DDC FILE COPY

Prepared for

DEPUTY FOR CONTROL AND COMMUNICATIONS SYSTEMS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Hanscom Air Force Base, Massachusetts

Project No. 6340
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
Contract No. F19628-77-C-0001

Approved for public release; distribution unlimited.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved for publication.

Robert V. Sillars
ROBERT V. SILLARS
Budget Analyst
Business Management Division

Edwin H. Deady
EDWIN H. DEADY, Major, USAF
Chief, Business Management Div
Satellite Communications Term SPO

Thomas E. Brand
THOMAS E. BRAND, Colonel, USAF
System Program Director
Satellite Communications Terminal SPO
Deputy for Control and
Communications Systems

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-78-114	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AFSATCOM LIFE CYCLE COST MODEL		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER MTR-3057
7. AUTHOR(s) J. H. James W. M. Stein		8. CONTRACT OR GRANT NUMBER(s) F19628-77-C-0001
9. PERFORMING ORGANIZATION NAME AND ADDRESS The MITRE Corp. Box 208 Bedford, MA 01730		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project No. 6340
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy for Control and Communications Systems Electronic Systems Division, AFSC Hanscom Air Force Base, MA 01731		12. REPORT DATE JUNE 1978
		13. NUMBER OF PAGES 147 150 P.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AFSATCOM
ANALYTIC MODEL
LIFE CYCLE COSTS
LOGISTICS
SITE BY SITE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Life Cycle Cost (LCC) mathematical model has been developed for the Air Force Satellite Communications System (AFSATCOM). The model (under FORTRAN program name SITELCC) has been used in various tradeoff analyses involving acquisition costs, operation and support costs, and system performance.

78 07 06 011

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

235 050 UC

20. ABSTRACT (concluded)

The AFSATCOM LCC Model provides for three echelons of maintenance, for communications terminal configurations of black boxes which may differ from base to base, and for reliability data which is a function of operating environment. In addition to LCC, the model calculates terminal availability as a result of initial sparing levels computed.

This report presents the detailed structure of the model. A description of the output reports with illustration from a sample model run is included.

ACKNOWLEDGMENTS

This report has been prepared by The MITRE Corporation under Project No. 6340. The contract is sponsored by the Electronic Systems Division, Air Force Systems Command, Hanscom Air Force Base, Massachusetts.

The authors wish to acknowledge the support of those who played a role in making the AFSATCOM Life Cycle Cost Model a reality, and to acknowledge assistance in bringing this report to fruition.

For support in the early developmental phase of the model, we are grateful to Lt. Col. Donald Marsey, former AFSATCOM Deputy Program Manager for Logistics (DPML), Maj. Delano J. Sylvester, current AFSATCOM DPML, and John J. Fabish, then of Sacramento ALC/MMER. At MITRE, Mary A. Lambert reviewed the LCC equations for their compatibility with MIL-STD-881.

Programming support for the development and maintenance of the model was begun by Nancy A. D. Mighdoll and Ava E. Schutzman, continued by Eileen T. Meeks, and later became the responsibility of Terry L. Evander.

Ava E. Schutzman wrote Appendix A, "Output Reports of the AFSATCOM Life Cycle Cost Model." The constructive criticism by Charles M. Plummer on the general nature of the overall report was invaluable.

The majority of the typing, editing, and considerable re-editing were done by Beverly J. Bamford, Dorothy F. Hamm, Marjorie R. O'Brien, and Donna G. Temple.

TABLE OF CONTENTS

LIST OF EXHIBITS

SECTION 1

INTRODUCTION

A life cycle cost (LCC) mathematical model has been developed for the Air Force Satellite Communications System (AFSATCOM) by The MITRE Corporation. One could classify it as an analytical accounting cost model, i.e., a systematic way of adding up component costs via a set of equations which model the physical configuration, performance, and logistics of the system. The model has been used in various tradeoff analyses involving acquisition costs, operation and support costs, and system performance. This AFSATCOM LCC Model has been fully programmed and is operational on an IBM-370/158 computer; the name of the FORTRAN program for this model is SITELCC.

A discussion of the AFSATCOM LCC Model requires a brief presentation of the AFSATCOM system configuration. The AFSATCOM system is comprised of several different types of communications stations, called "terminals." There are approximately 30 different terminal types. Each is a self-contained unit which can communicate with other units via a satellite relay. The terminals operate either at fixed ground locations, transportable ground locations, or in airborne platforms. The terminals consist of units (or black boxes) for which diagnosis and replacement is performed at the organizational level, hence these are often referred to as line replaceable units, or LRUs. By definition, the LRUs are removed and replaced to repair a failed terminal. The AFSATCOM system contains approximately 120 different LRU types. The LRU is composed of shop replaceable units, or SRUs. These are usually printed circuit cards and are removed from the failed LRU in the repair shop. There are about 300 different types of SRUs. Some SRUs are composed of other SRUs, but for the most part an SRU is the lowest level of indenture repairable in the system, in the following sense: SRUs are either discarded upon failure or are repaired by replacement of piece parts, e.g., integrated circuits, capacitors, etc. To support this system, approximately 100 different types of special AFSATCOM support equipment items are involved.

The logistics of the AFSATCOM system are as follows: The terminals (or their host aircraft, in the case of airborne terminals) are located at approximately 90 bases, including both continental U.S. and overseas. Organizational-level maintenance is backed-up by base-level and depot-level repair capabilities. The maximum possible number of repair facilities would occur when there

were one repair facility on each base. However, bases may be grouped for the purpose of sharing an intermediate-level repair facility. Various schemes of groupings, or centralization, have been considered. One plan allows for 46 intermediate maintenance facilities. Another concept, using larger groupings (typically 5 or 10 bases per group) reduces this number to 25. In both schemes, there will still be stand-alone bases, i.e., bases which are not part of any grouping. The AFSATCOM system is to be supported by one depot.

1.1 Special Features of the Model

The AFSATCOM LCC Model is basically structured at the LRU level of Work Breakdown Structure (WBS) indenture,* although certain calculations are performed at the SRU, terminal, or system level where appropriate. For a given LRU, at each specified site, planned operating hours and expected mean time between failures (MTBF) are used to calculate the expected number of LRU failures during the lifetime of the system. Given these expected failures, the resulting support costs are calculated and aggregated at the LRU, terminal, and system level. Non-failure-related costs, such as those of acquisition, are calculated and aggregated similarly.

Historically, the model was developed from an early version of the AFLC Logistics Support Cost (LSC) Model [1]. The AFSATCOM LCC Model calculates costs in a way similar to that of the LSC Model, but possesses special features tailored to AFSATCOM and not available in the LSC Model.

In the AFSATCOM structure, a specific type of LRU may be placed in multiple terminals. In addition to the standard allocation of costs to terminals, the AFSATCOM LCC Model allows for visibility of cost by LRU type. Most accounting LCC models take standard inputs which fail to recognize that a certain type of LRU may operate in multiple subsystems. In the AFSATCOM LCC Model, LRU data is retained in memory in order to allow the model to recognize a given

*For the purpose of this documentation, "WBS indenture" will refer only to the Work Breakdown Structure by hardware configuration, i.e., total system, terminals, LRUs, SRUs. Other forms of Work Breakdown Structure for life cycle cost models, such as by cost element, will be discussed but not referred to as "level of indenture."

LRU in multiple terminals and to facilitate sensitivity analyses. The storage requirement to support this capability is very large (384K bytes of core storage). The LSC program retains the data for only one LRU at a time, never returning to previous LRUs during the computation process. A much smaller but less flexible program results.

Since AFSATCOM has terminals operating in several environments, the AFSATCOM LCC Model allows an LRU to have any one of three input reliabilities depending upon the environment in which the terminal is placed: ground fixed, ground transportable, or airborne.

The various terminal configurations in AFSATCOM differ widely from base to base. Most accounting LCC models are designed to accept standardized inputs, thereby implying identical base configurations. To apply such models to the "average AFSATCOM base" would introduce a major source of uncertainty and deny visibility of costs to the specific terminals. The AFSATCOM LCC Model employs operational data (e.g., terminal quantity, type, and utilization) as specified for each base. The model calculates for each site (i.e., for each base and for the depot) the separate costs of sparing, support equipment and training.

In addition to the computation of life cycle costs, the AFSATCOM LCC Model performs calculations for terminal availability by base as a result of LRU spares calculation.

Data requirements for the model are extensive, and hence the model is most applicable later in the development phase when preproduction reliability data is available. However, a planning version can be set up using only a few sites, early estimates of mean time between failures (MTBF) and mean time to repair (MTTR), or early mean time between demands (MTBD) and mean down time (MDT) estimates, possibly based on cost-estimating relationships, and early system configurations so that design tradeoffs can be made. (More complete definitions of MTBF, MTTR, MTBD, and MDT may be found in the Glossary at the end of this document.)

1.2 Applications for AFSATCOM

At MITRE, this model has been used in support of AFSATCOM system configuration and logistics tradeoff analyses, as well as to make calculations of initial sparing and support equipment requirements for the production contract. The configuration analyses supported

by the model stem from an AFSATCOM decision to purchase the LRUs which are assembled to form terminals rather than to buy whole terminals. In order to make tradeoff studies among system configurations with the greatest possible ease, the model is designed to accept as user's input the structure of SRUs in LRUs, of LRUs in terminals, and of terminals on bases.

AFSATCOM logistics studies which have been served by this model include a computation of the potential savings available in system life cycle cost when abandoning the traditional concept of each base having its own repair facility, in favor of grouping bases, with one member of each group serving as the "centralized intermediate maintenance facility," or CIMF, for that group. This study revealed a potential savings of $35 million over a ten-year life cycle when adopting this "centralized" maintenance posture, with negligible impact upon terminal availability.

Another important use of the AFSATCOM LCC Model has been to calculate the initial sparing requirements (size of inventories), for each LRU type, at each base and at the depot, and to compute base and depot support equipment requirements, in order to establish procurement size for the production contract. As a part of this study, the AFSATCOM LCC Model was used to assess the cost-effectiveness of using maintenance bench sets ("hot mock-ups," installed at bases designated by the user, to test LRUs in an equivalent failure-free environment) along with, or in place of, special AFSATCOM support equipment.

Another feature of the AFSATCOM LCC Model is that cost elements which are not inherently system-wide are attributable to the various LRU types and/or terminal types for which the costs are incurred. The model displays this portion of life cycle cost broken down by LRU and terminal. The various LRU types and terminal types are ranked by their prorated share of life cycle cost, permitting identification of the more significant cost-driving LRUs within AFSATCOM, so as to pinpoint those specific components of the system where further efforts would have the greatest potential impact on cost reduction.

1.3 Cost Elements

The basic cost elements which are associated with the AFSATCOM life cycle after the validation phase are shown in Exhibit 1. These cost elements are consistent with the military standard work breakdown structures of MIL-STD-881 (Reference [2]), with additional

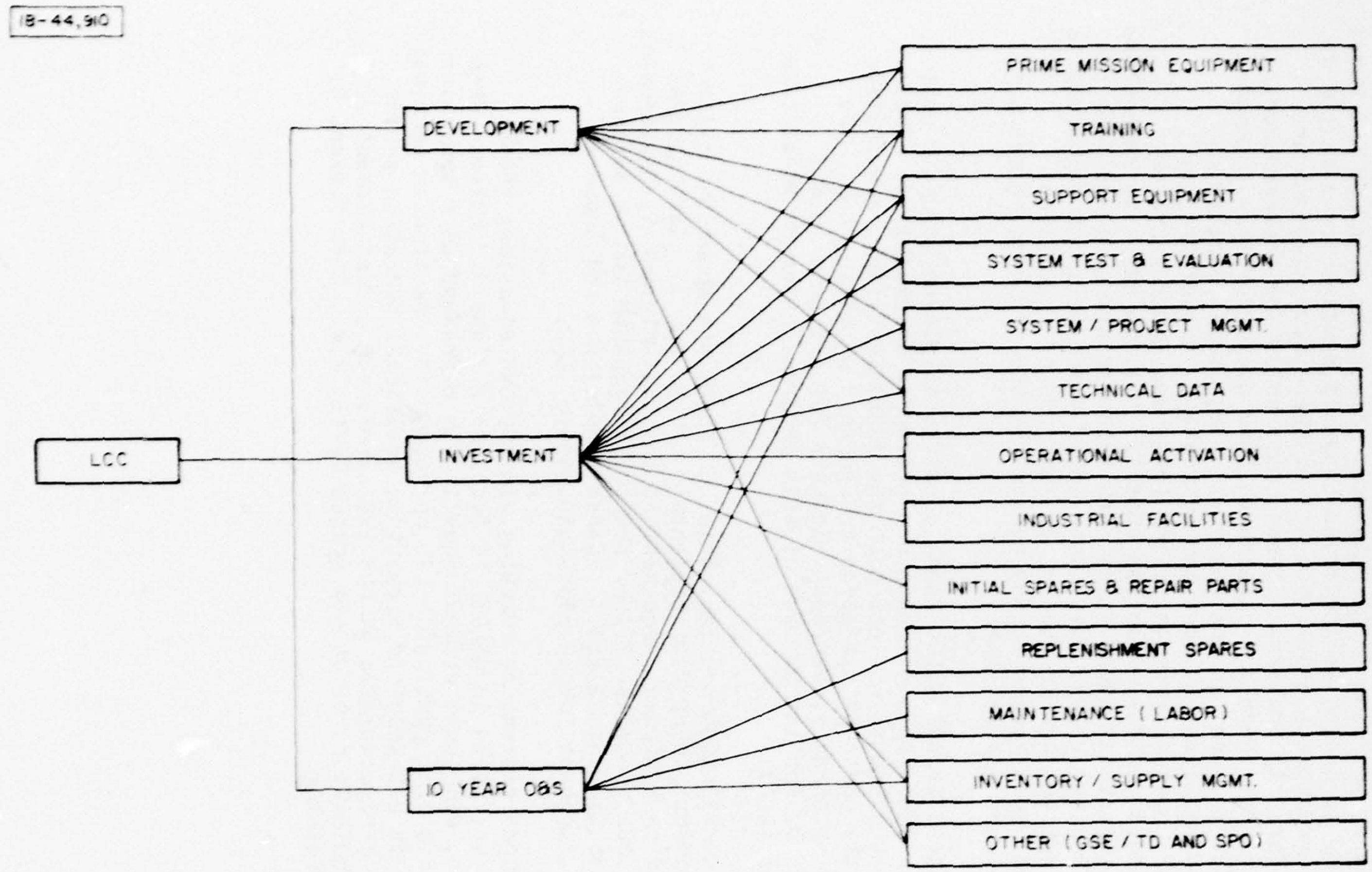


EXHIBIT I
COST ELEMENTS WHICH MAKE UP THE LIFE CYCLE COST AFTER THE VALIDATION PHASE

categories as per basic AFLC guidance. Since the AFSATCOM LCC Model is intended to assist in logistics tradeoff studies for AFSATCOM in the post-development phase, not all of these cost elements are required for this analysis. Those costs which are incurred during the development phase are considered sunk costs for this LCC model and are not included in the analysis. Industrial Facilities, Operational Activation, Test and Evaluation, System/Project Management, Systems Program Office (SPO) and General System Engineering/Technical Direction (GSE/TD) will be the same regardless of the alternatives under study, and likewise are excluded from the model. In other words, only those costs which will not be common to all alternatives are included. In the case of Operational Activation, some variances may occur, but the differences are not expected to be significant.

The basic AFSATCOM LCC Model consists of eleven separate cost elements. These cost elements are presented in Exhibit 2. These eleven cost elements reflect both the AFSATCOM primary acquisition cost and the costs of operation and support of the system. The aggregate of these eleven cost elements for all LRUs in all terminals is, for the purpose of this program, referred to as life cycle cost (LCC).

For the AFSATCOM program, this LCC Model has found the major cost components to be Cost Elements 1, 2, 5, and 7. Cost Element 1, Prime Mission Equipment Acquisition, and Cost Element 5, Replacement LRUs and SRUs, comprise 77% of the total AFSATCOM LCC as defined above; Cost Elements 2 and 7, Spares Acquisition and Support Equipment, account for an additional 15% of LCC.

Each cost element is computed via its own equation; these equations are given in detail in Sections 2.1 and 3.1 below. When applicable, each cost element equation is expressed as a summation of the costs of a particular LRU operating in a particular terminal. When this is not possible without an artificial proration scheme, the costs are calculated at the LRU level, e.g., Cost Element 2, Spares Acquisition, or at the system level, e.g., Cost Element 8, Initial Training.

1. Prime Mission Equipment (Hardware) Acquisition
2. Spares Acquisition
3. Maintenance Bench Sets
4. "Off-Equipment" Repairs
5. Replacement LRUs and SRUs
6. "On-Equipment" (Organizational Level) Repairs
7. Support Equipment (SE)
8. Initial Training
9. Recurring Training
10. New Item Inventory Management
11. Technical Data

Exhibit 2. The Eleven Cost Elements for the AFSATCOM LCC Model.

The equation of Cost Element 2 requires the number of spares of each LRU at each base, and the number of spares of each LRU at the depot. These quantities are calculated by the Sparing Routine, discussed in Sections 2.2 and 3.2 below.

As a side calculation, the AFSATCOM LCC Model develops the terminal availability at each base. The equations used are given in Sections 2.3 and 3.3. The probabilities of backordering, i.e., of needing replenishment LRUs after inventory has been depleted, are received as inputs from the Sparing Routine.

1.4 Maintenance Postures

The AFSATCOM LCC Model provides for two maintenance postures: "non-centralized" maintenance and "centralized" maintenance. In the "non-centralized" maintenance posture, each base is capable of providing base repair for any LRU type designated as base repairable. In the "centralized" maintenance posture, some (or all) of the bases are assigned to groups within which base-level maintenance is pooled. Thus, in the centralized maintenance posture any bases not assigned to a group will perform base repair exactly as in the non-centralized maintenance posture; each grouping of bases will have one base assigned as the "centralized intermediate maintenance facility" or CIMF, and all base-level maintenance of the group will be performed at the CIMF.

1.5 Repair-Level Designations

Two other repair-level designations are possible for LRU types, besides the base-repair designation discussed above. These are depot-level repair and condemnation (no repair) upon failure. Under the "non-centralized" maintenance posture, the action of packaging and shipping to the depot, when warranted, is initiated at the base at which the failure occurs. Under the "centralized" maintenance posture, all failures are shipped to the CIMF; whether further shipping to the depot is warranted is decided at the CIMF.

SECTION 2

THE AFSATCOM LCC MODEL WITH "NON-CENTRALIZED" MAINTENANCE POSTURE

For simplicity of documentation, the LCC Routine, the Sparing Routine, and the Availability Routine will first be presented below (Sections 2.1, 2.2, and 2.3) in their entirety, as they apply to the "non-centralized" maintenance posture. The "centralized" maintenance posture will be discussed in Section 3, where the manner of inputting a given configuration of stand-alone bases (i.e., bases not assigned to any group), groupings, and CIMF bases will first be presented. The documentation will then return to the LCC Routine, the Sparing Routine, and the Availability Routine (Sections 3.1, 3.2, and 3.3); only the necessary changes to convert from "non-centralized" maintenance posture to "centralized" maintenance posture will be discussed in those sections.

Notation used throughout will conform to that of FORTRAN, with exceptions for summations, exponential function, and greatest-integer function. Multiplication will be denoted by an asterisk, e.g., A*B, and indices will be written in capital letters. Summations will be represented by a summation symbol, $\sum$, with the index of the summation printed directly beneath it. The upper limit of the summation will not be printed; the maximum value for that index will be implied in all cases. Throughout, index I will represent LRU type, index J will represent SRU type (appearing in Cost Element 5 only), index K will represent terminal type, index NS will represent specific bases, and index L will represent the SERD (Support Equipment Review Document) item number for support equipment (SE). In Cost Element 8, the index M will represent the category number in the grouping of LRUs into categories for training purposes.

In the actual FORTRAN program for the AFSATCOM Life Cycle Cost Model, SITELCC, user-defined upper limits are provided for, to be associated with summations on indices I, J, K, NS, and L. These need not be as great as the FORTRAN dimension limits of the computer program. These dimension limits, which determine the capacity of the model, are as follows: 135 different LRU types, up to 40 SRU types per LRU type, 30 different terminal types, 95 sites (94 bases plus one depot), and up to 200 different kinds of support equipment items.

Documentation of the AFSATCOM LCC Model will be addressed to the case of a single depot for the depot-level repair of AFSATCOM LRUs and SRUs. As such, it will not be necessary to provide an index for depots. However, the program is readily expandable to a case of more than one depot; many of the variables which are presented here as depot-dependent and without index NS exist in the program as a function of NS preceded by program logic to ascertain when the value of NS exceeds the greatest value representing a base. However, such program expansion would require the introduction of vectors or matrices to assign the appropriate depot choice for given LRU type, terminal type and/or base.

Brief definitions are included as needed for the discussion. The reader is also advised to consult the Glossary at the end of this document for more thorough definitions of the FORTRAN variables introduced here, and the units in which these variables are measured. The source of numerical data for each input variable (i.e., parameter) is included in the Glossary entry. For FORTRAN variables which are computed internally by the model, the Glossary entry references the appropriate section of the text for the defining equation(s).

2.1 The LCC Cost Element Equations

The eleven cost elements of the AFSATCOM LCC Model are listed in Exhibit 2. The detailed equations for these cost elements are presented in this section. The units for each cost element are in total dollars expended over the operational service life of the system.

2.1.1 Cost Element 1 (Hardware Acquisition)

Cost Element 1 is the acquisition cost of primary mission equipment, namely, the cost of buying the AFSATCOM terminals. Due to an AFSATCOM decision to purchase the LRUs which are assembled to form terminals rather than to buy whole terminals, this computation is performed on an LRU basis. This procedure allows for last minute configuration changes and the ability to design terminals for specific locations. The equation for Cost Element 1 is

$$SC(1) = \sum_{K} \sum_{I} QPA(I,K)*NTS(K)*UC(I)$$

where QPA(I,K) is the quantity of LRUs of type I installed in a terminal of type K, NTS(K) is the total number of terminals of type K to be purchased, and UC(I) is the unit cost for an LRU of type I.

The quantity NTS(K) is computed internally by the model,

$$NTS(K) = \sum_{NS} IT(K,NS)$$

where IT(K,NS) is the number of terminals of type K to be operated at base NS, a user's input to the model. (<u>Note</u>: In order to eliminate the inefficiency and expense of storing in core a matrix which is relatively sparse, a provision exists within the AFSATCOM LCC Model whereby any subset of the matrix [IT(K,NS)] within which only one terminal per base is assigned can be stored in core as a one-dimensional array.)

This cost element can be broken down according to LRU type or terminal type. That portion of Cost Element 1 attributable to LRU type I is calculated as in the above equation but with summation on K only. That portion of Cost Element 1 attributable to terminal type K is calculated as in the above equation but with summation on I only.

2.1.2 <u>Cost Element 2 (Spares Acquisition)</u>

Cost Element 2 is the spares acquisition cost. This cost element consists of the initial investment costs of LRU spares necessary to support the base and depot repair pipelines, to protect against fluctuations in demand and in pipeline time. The equation includes the costs of inventories at each base and at the depot,

$$SC(2) = \sum_{I} [\sum_{NS} SB(I,NS) + SD(I)]*UC(I)$$

where SB(I,NS) is the number of spares of LRU type I to be acquired for inventory at base NS, SD(I) is the number of spares of LRU type I to be acquired for inventory at the depot, and UC(I) is the unit cost (for initial provisioning) of an LRU of type I.

The inputs SB(I,NS) and SD(I) are calculated by the Sparing Routine, discussed in Section 2.2 below. In particular, SB(I,NS) is the Sparing Routine output variable QS when the Sparing Routine input variable AS is as discussed in Subsection 2.2.2.1, "Load Factor for Base Inventory;" SD(I) is Sparing Routine output variable QS when Sparing Routine input variable AS is as discussed in Subsection 2.2.2.2, "Load Factor for Depot Inventory."

This cost element can be broken down according to LRU type. That portion of Cost Element 2 attributable to LRU type I would be found as in the above expression but with the summation on I omitted.

2.1.3 Cost Element 3 (Maintenance Bench Sets)

Cost Element 3 is the acquisition cost of maintenance bench sets ("hot mock-ups"). At certain bases designated by the user, a maintenance bench set will be installed to exercise the built-in test equipment (BITE) of an LRU in an equivalent failure-free environment, in the course of isolating malfunctions at the LRU level. The model can handle up to six different types of maintenance bench sets available for the various selected bases. When a maintenance bench set exists at a given base, special AFSATCOM support equipment need not necessarily be purchased for that base. This information is carried in the coding of the six available maintenance bench set types. The user specifies which of these six values designate that special AFSATCOM support equipment is also purchased for the given base; for the remainder (if any), special AFSATCOM support equipment is <u>not</u> also purchased for a base when that type maintenance bench set is purchased for the base. (See also Cost Element 7, Support Equipment.)

The equation for Cost Element 3 is

$$SC(3) = \sum_{NS} \sum_{I} HMU(NHM(NS),I)*UC(I)*(1 + PIUP*AMAH)$$

where NHM(NS) is the type of maintenance bench set used at base NS (zero if no maintenance bench set at base NS, otherwise coded to designate whether or not special AFSATCOM support equipment is also purchased for base NS), and HMU(NHM,I) is the quantity of LRUs of type I installed in maintenance bench set type NHM. Typically, special "LRUs" are defined for this purpose.

The term PIUP*AMAH is the added-on fraction to allow for the maintenance of the maintenance bench sets themselves, over the life cycle.

This cost element can be broken down according to LRU type. That portion of Cost Element 3 attributable to LRU type I would be found as in the above expression but with the summation on I omitted.

2.1.4 Cost Element 4 ("Off-Equipment" Repairs)

Cost Element 4 is the life cycle cost of "off-equipment" repairs, i.e., repairs at base and depot levels performed on LRUs which must be removed from their respective terminals. Included is the labor cost incurred for time to diagnose, repair or attempt to repair, at the LRU level of indenture. The equation for this cost element also includes the packing and shipping cost incurred during the life cycle of such LRUs. The cost of removal and replacement of LRUs is included with Cost Element 6, the sum of all costs due to "on-equipment" repairs and maintenance, i.e., work performed at the terminals. Both labor and materials costs associated with levels of indenture lower than the LRU are included with Cost Element 5. For any LRU which does not further subdivide into an SRU level of indenture, the labor cost of repair is accounted for in Cost Element 4 and the materials cost of repair is included with Cost Element 5.

The equation for Cost Element 4 is as follows:

$$SC(4) = 12*PIUP* \sum_{NS} \sum_{K} \sum_{I} FAIL(I,K,NS)*(HPF(I) + RTF(I,NS))$$

where PIUP is the operational service life of the system, in years, FAIL(I,K,NS) is the expected number of removals per month of LRU type I in terminal type K at base NS, HPF(I) is the expected manpower cost to repair an LRU of type I, and RTF(I,NS) is the expected round trip packing and shipping cost for an LRU of type I from base NS, given that the LRU has been removed for repairs. The units of HPF(I) and RTF(I,NS) are dollars per removal.

The components FAIL(I,K,NS), HPF(I), and RTF(I,NS) are computed from more basic inputs:

```
FAIL(I,K,NS) = QPA(I,K)*IT(K,NS)*(1-RIP(I))*ATOH(K,NS)
                         *MFAC(LE(K))/MOTBMA(I,LE(K))

HPF(I) = BLR*RTS(I)*RT(I)*BMF*KB
         + DLR*NRTS(I)*RT(I)*DMF*KD
```

and

```
RTF(I,NS) = PS(LO(NS))*PWR(LO(NS))*KB
                       *(2*NRTS(I) + COND(I))*WT(I).
```

All FORTRAN variables which appear above are defined in the Glossary, along with identification of the responsible authority or source of numerical data for input variables. Briefly, the monthly failure rate FAIL(I,K,NS) increases with the quantity QPA(I,K) of LRUs of type I in terminal type K and with the number IT(K,NS) of terminals of type K at base NS, allowing that only the fraction 1-RIP(I) of maintenance actions involving LRUs of type I will result in "off-equipment" repair, that average operating time per month ATOH(K,NS) varies with base as well as with terminal type, and that both predicted and operational mean operating time between maintenance actions are functions of the environment LE(K) of terminals of type K (i.e., ground fixed, ground transportable, or airborne). The variable MOTBMA(I,LE) is the Contractor's predicted mean operating time between maintenance actions for an LRU of type I operating in environment LE, and MFAC(LE) is the reliability factor which converts predicted failure rate (reciprocal of MOTBMA(I,LE)) to operational failure rate as a function of environment LE.

The expected manpower repair cost HPF(I) for each "off-equipment" repair of LRU type I is a sum of two terms, one term for base repair weighted by the fraction RTS(I) of removals expected to be repaired at the base, and the other term for depot repair weighted by the fraction NRTS(I) of removals expected to be returned to the depot for repair. Note: The average number of man-hours required to repair LRU type I, RT(I), includes time to diagnose, attempt to repair.

The principal factors of the round trip packing and shipping cost RTF(I,NS) for LRU type I from base NS are the string

PS(LO(NS))*PWR(LO(NS))*KB

which represents effective one-way cost per pound net (unpacked) as a function of the location LO(NS) of base NS (continental U.S. or overseas), and the factor

(2*NRTS(I) + COND(I))*WT(I)

which tallies twice the net weight WT(I) of LRU type I if on a round trip to the depot for repair and return, once the net weight if on a one-way trip from the depot to replace a condemned LRU.

The factors BMF, DMF, KB, and KD are employed here and throughout the AFSATCOM LCC Model as follows: BMF is a base repair maintenance factor, by which repair time RT(I) is multiplied, to include time to get test equipment, parts, etc. DMF is a depot repair maintenance factor, to be applied to RT(I) when the repair is performed at the depot. KB is a factor to account for increased damage due to handling, and maintenance damage, at the base; KD is a similar factor to account for such increase in damage at the depot. The factors KB and KD are intended as multipliers to the failure rate, FAIL(I,K,NS). This will often be accomplished indirectly, as via HFF(I) and RTF(I,NS) in the above computations.

The factor 12*PIUP which occurs in Cost Element 4 converts monthly cost into a total cost over the operational service life of the system. The AFSATCOM LCC Model actually allows for use of a discount factor if an interest rate is provided. The programmed function is

```
DFC(A,B,R) =  B - A                            if  R = 0
           =  [EXP(-A*R) - EXP(-B*R)]/R        if  R > 0
```

which evaluates the continuously discounted sum of a series of payments beginning at time A and ending at time B, for interest rate R. Using A=0, B=12*PIUP, and R=0, the multiplier 12*PIUP results. For R≠0, a <u>monthly</u> interest rate must be used.

The inputs RTS(I), NRTS(I), COND(I) are the fraction of removals of LRU type I which are expected to be repaired at the base, returned to the depot for repair, condemmed upon failure, respectively. These inputs are based upon the results of an Optimum Repair-Level Analysis (ORLA), as defined in AFLCM/AFSCM 800-4 (Reference [3]), which assigns one of the decisions "base repair," "depot repair," or "discard" to each LRU type. In addition, RTS(I), NRTS(I), and COND(I) involve the variables WOR, the fraction of

failures (of normally repairable LRUs) which can no longer be repaired, due to wearout, and NRT, the fraction of LRUs normally base-repairable which are sent to the depot due to the severity of their damage ("basket cases"). These computations are summarized in Exhibit 3.

Cost Element 4 can be broken down according to LRU type or terminal type. That portion of the cost element attributable to LRU type I is calculated as above but with summations on K and NS only. That portion of Cost Element 4 attributable to terminal type K is calculated as above but with summations on I and NS only.

In the actual FORTRAN program, SITELCC, for the AFSATCOM LCC Model, the three-dimensional entity FAIL(I,K,NS) is computed as a scalar and summed at the innermost level of a three-level nest of DO-loops. Thus only the following two-dimensional arrays need be declared for core storage:

$$XF(I,K) = \sum_{NS} FAIL(I,K,NS)$$

$$XFB(I,NS) = \sum_{K} FAIL(I,K,NS).$$

These variables have the following physical interpretations: XF(I,K) is the expected number of removals (failures) per month of LRU type I in terminal type K, and XFB(I,NS) is the expected number of removals (failures) per month of LRU type I at base NS. For the computations and prorations to LRU types I and terminal types K, SITELCC employs for Cost Element 4 both the XF(I,K) and the XFB(I,NS) arrays.

Note: A useful attribute of an LRU is the total expected number of failures of that LRU type over the life cycle. This quantity can be used for quick cost per failure calculations and repair/discard tradeoffs. Equating failures and removals for this purpose,

$$XFL(I) = 12{*}PIUP{*} \sum_{NS} \sum_{K} FAIL(I,K,NS)$$

$$= 12{*}PIUP{*} \sum_{K} XF(I,K).$$

Equivalently (see above),

$$XFL(I) = 12{*}PIUP{*} \sum_{NS} XFB(I,NS).$$

	ORLA decision "base repair" for LRU type I	ORLA decision "depot repair" for LRU type I	ORLA decision "discard" for LRU type I
RTS(I)	1-WOR-NRT	0	0
NRTS(I)	NRT	1-WOR	0
COND(I)	WOR	WOR	1

Exhibit 3. Computation of RTS(I), NRTS(I), and COND(I) Based upon Results of Optimum Repair-Level Analysis (ORLA) and Variables WOR and NRT.

The computed values of XFL(I) appear in the output of the AFSATCOM LCC Model as a convenience to the user.

2.1.5 Cost Element 5 (Replacement LRUs and SRUs)

The equation for this cost element represents the life cycle cost of replacement LRUs and SRUs. Included here are costs of repairable LRUs purchased to replace those worn out beyond feasibility of repair, as well as replacements for LRUs of types designated for discard upon failure. Costs associated with levels of indenture lower than the LRU are lumped together into a single average SRU exchange cost for each LRU type. This SRU exchange cost is an average cost per failure (over the life cycle) to repair SRUs when they are repairable, to buy replacement SRUs when they are disposable.

Cost Element 5 is computed as

$$SC(5) = 12*PIUP \sum_{NS} \sum_{K} \sum_{I} FAIL(I,K,NS)*[COND(I)*UC(I) + (RTS(I)*KB + NRTS(I)*KD)*ASEC(I)].$$

For LRU types I with nonzero condemnation fraction COND(I) (which includes the wearout rate WOR, as per Exhibit 3), the unit costs UC(I) accrue over the life cycle. Otherwise, for the fraction

$$1 - COND(I) = RTS(I) + NRTS(I),$$

the costs which accrue are the average SRU exchange costs introduced in the preceding paragraph. The average SRU exchange cost for LRU type I is denoted ASEC(I). Specifically, ASEC(I) is an average cost per maintenance action resulting from failure of an LRU of type I, exclusive of the labor cost incurred for time to diagnose, repair or attempt to repair, at the LRU level of indenture. This average is comprised of the failure-rate-weighted costs of the SRUs in the LRU, using repair cost (including cost of labor, materials, SE, spares, packing and shipping, etc.) for repairable SRUs, replacement costs for disposable SRUs. For any LRU type which does not further subdivide into an SRU level of indenture, ASEC(I) represents the average cost of repair materials only, per failure.

The coefficient of ASEC(I) in the equation for Cost Element 5 includes with RTS(I) and NRTS(I), respectively, the multipliers KB and KD to convert FAIL(I,K,NS) from expected number of removals per month to expected number of actual failures per month, according to whether handling and maintenance are performed at the base or at the depot.

The input ASEC(I) is created by an auxiliary program which uses the cost per failure of each SRU as a function of repair level designated by an ORLA Routine (see, e.g., [3]) run for the SRUs. This auxiliary program receives as input a data file which carries all necessary information as to the breakdown structure of LRUs into SRUs. (Unlike the breakdown structure of terminals into LRUs, which is input and stored as the matrix [QPA(I,K)], the breakdown structure of LRUs into SRUs is not stored in matrix form due to the size and relative sparsity, i.e., large number of zero entries, that such a matrix would possess.)

In the case where LRU type I further subdivides into SRUs, the equation used to compute ASEC(I) is

$$\mathrm{ASEC(I)} = \sum_{J} \mathrm{MOTBMA(I,1)/MOTBMA(J,1)} * [\mathrm{RTS(J)*CPFB(J)} + \mathrm{NRTS(J)*CPFD(J)} + \mathrm{COND(J)*CPFS(J)}]$$

where index J identifies the SRU type, and the summation is taken on each SRU in the given LRU type I, to allow for the possibility of more than one SRU of the same type in the LRU. Here MOTBMA(J,LE) is the Contractor's predicted mean operating time between maintenance actions on an SRU of type J, and MOTBMA(I,LE) is the Contractor's predicted mean operating time between maintenance actions for an LRU of type I, when operating in environment LE; the representative environment selected is LE=1, or Ground Fixed. The variables RTS(J), NRTS(J), and COND(J) are outputs from an ORLA Routine [3] for SRU type J, with similar meaning as given earlier for LRU type: the fraction of removals of SRU type J which are expected to be repaired at the base, returned to the depot for repair, and condemned upon failure, respectively. Dividing the life cycle cost for SRU type J, for each repair-level designation, by the total number of failures of SRU type J expected over the life cycle, the

SITEORLA Routine* computes the inputs CPFB(J), CPFD(J), and CPFS(J) for the above equation. These therefore represent the cost per failure of SRU type J given base repair, depot repair, and discard upon failure, respectively.

The expression

$$MOTBMA(I,1)/MOTBMA(J,1)$$

which appears as a coefficient in the equation for ASEC(I), above, is the probability of failure of an SRU of type J in an LRU of type I, and hence accomplishes the failure-rate weighting of the cost terms found in the brackets. To see this, rewrite this expression as

$$[1/MOTBMA(J,1)] \;/\; [1/MOTBMA(I,1)]$$

which is merely a ratio of the failure rate of an SRU of type J to the failure rate of an LRU of type I. By consistency of Contractor's data,

$$\sum_{J} [1/MOTBMA(J,1)] = 1/MOTBMA(I,1)$$

(with the summation taken on <u>each</u> SRU in LRU type I, to allow for the possibility of more than one SRU of the same type J). Hence

$$\sum_{J} [1/MOTBMA(J,1)] \;/\; [1/MOTBMA(I,1)] = 1$$

as should be the case for probabilities on J with a given I.

In the case where LRU type I does not further subdivide into SRUs, then the auxiliary program which computes ASEC(I) sets

*SITEORLA is the name of a site-specific ORLA Routine developed at The MITRE Corporation, extending upon the 1974 work of J. J. Fabish (Reference [4]), then of Sacramento ALC/MMER, to support AFSATCOM life cycle cost analyses.

$$ASEC(I) = RM(I)$$

where RM(I) is the average repair materials cost per failure of LRU type I, an input provided by the user.

As in Cost Element 4, the factor 12*PIUP is replaced by the value of a continuously discounted sum when a monthly interest rate is provided.

This cost element can be broken down according to LRU type or terminal type. That portion of Cost Element 5 attributable to LRU type I is calculated as in the above equation but with summations on K and NS only. That portion of Cost Element 5 attributable to terminal type K is calculated as in the above equation but with summations on I and NS only.

In the actual FORTRAN program, SITELCC, for the AFSATCOM LCC Model, the three-dimensional entity FAIL(I,K,NS) is computed as a scalar and summed into two-dimensional arrays, as discussed above for Cost Element 4. In the computations of Cost Element 5, only the XF(I,K) array is employed.

2.1.6 Cost Element 6 (Organizational Level Repairs)

Cost Element 6 is the life cycle cost of all organizational level "on-equipment" repairs, i.e., work performed on LRUs at their respective terminals. This cost element is comprised of unscheduled in-place maintenance, scheduled in-place maintenance, and LRU removals and replacements. Unscheduled in-place maintenance implies those organizational level repair actions which are performed on a failed LRU without its removal from the terminal. Scheduled in-place maintenance consists of inspections required at intervals as specified by the contractor. Included with Cost Element 6 as "on-equipment" repairs are all removals and replacements due to LRU failures which necessitate further "off-equipment" repair action, i.e., at base or depot repair levels.

The equation for this cost element is

$$SC(6) = 12*PIUP* \sum_{NS} \sum_{K} \sum_{I} BLR*QPA(I,K)*IT(K,NS)$$

$$*\left[\frac{RIP(I)*IMH(I)*ATOH(K,NS)*MFAC(LE(K))}{MOTBMA(I,LE(K))} + \frac{SMH(I)}{SMI(I)}\right]$$

$$+ 12*PIUP* \sum_{NS} \sum_{K} \sum_{I} BLR*FAIL(I,K,NS)*RMH(I).$$

The symmetry in this equation is revealed by substituting for FAIL(I,K,NS) the expression given in the description for Cost Element 4, from which the final term of the above equation becomes

$$12*PIUP* \sum_{NS} \sum_{K} \sum_{I} BLR*QPA(I,K)*IT(K,NS)$$

$$*\left[\frac{(1-RIP(I))*RMH(I)*ATOH(K,NS)*MFAC(LE(K))}{MOTBMA(I,LE(K))}\right].$$

Here, in addition to FORTRAN variables presented in the earlier cost element equations, IMH(I) is the average number of man-hours required to repair LRU type I in place (i.e., without its removal from the terminal), assuming that such a maintenance action is required, SMH(I) is the average number of man-hours required to perform scheduled maintenance (including preventive maintenance, preflight, postflight, periodic inspections of the subsystems, and any remove and replace time) on LRU type I, SMI(I) is the average scheduled maintenance interval, in months, for LRU type I, and RMH(I) is the average number of man-hours required to remove and replace LRU type I. The quantities IMH(I), SMH(I), and RMH(I) in reality vary with terminal type K as well as with LRU type I. However, the life cycle cost has been found to be sufficiently insensitive to variations in IMH(I), SMH(I), and RMH(I), so that it is permissible to consider these quantities as functions of LRU type I only, averaged over the various terminal types K which may contain LRU type I.

As in Cost Element 4, the factor 12*PIUP is replaced by the value of a continuously discounted sum when a monthly interest rate is provided.

This cost element can be broken down according to LRU type or terminal type. That portion of Cost Element 6 attributable to LRU type I is calculated as in the above equation but with summations on K and NS only. That portion of Cost Element 6 attributable to terminal type K is calculated as in the above equation but with summations on I and NS only.

In the actual FORTRAN program, SITELCC, for the AFSATCOM LCC Model, the three-dimensional entity FAIL(I,K,NS) is computed as a scalar and summed into two-dimensional arrays, as discussed previously for Cost Element 4. In the computations of Cost Element 6, only the XF(I,K) array is employed.

2.1.7 Cost Element 7 (Support Equipment)

Cost Element 7 is the life cycle cost of AFSATCOM support equipment, SE. The following equation describes the cost of all SE purchased for each maintenance facility (the various bases and the depot), with an added-on fraction to allow for the maintenance of the SE itself, including both labor and parts, over the AFSATCOM life cycle:

$$SC(7) = \sum_{L} \left[\sum_{NS} NAPB(L,NS) + NAPD(L) \right] * CA(L) * (1 + PIUP * AMA(L))$$

where NAPB(L,NS) is the number of SE items of SERD item number L purchased for base NS, NAPD(L) is the number of SE items of SERD item number L purchased for the depot, CA(L) is the unit price of SE item L, and PIUP*AMA(L) is the added-on fraction to allow for the maintenance of SE item L over the life cycle.

The numbers of SE items to be purchased, NAPB(L,NS) and NAPD(L), are established as follows:

$$NAPB(L,NS) = [ERHAB(L,NS)/BAA]^{+}$$

$$NAPD(L) = [ERHAD(L)/DAA]^{+}$$

where $[\ldots]^{+}$ denotes rounding up to the next higher integer, ERHAB(L,NS) and ERHAD(L) represent the expected utilization of SE item L in man-hours/month at base NS and at the depot, respectively, and BAA, DAA are the total available active work time in hours/month at base, depot repair shops, respectively;

$$ERHAB(L,NS) = \sum_{I}\sum_{K} ERHB(I,K,NS)*A(I,L)$$

$$ERHAD(L) = \sum_{I}\sum_{K} ERHD(I,K)*A(I,L)$$

with

$$ERHB(I,K,NS) = FAIL(I,K,NS)*RTS(I)*RT(I)*BMF*KB$$

$$ERHD(I,K) = \sum_{NS} FAIL(I,K,NS)*NRTS(I)*RT(I)*DMF*KD,$$

and A(I,L)=1 if LRU type I is supported by SE item L, A(I,L)=0 otherwise. The LRU-SE usage or cross-reference matrix [A(I,L)] is a user's input to the AFSATCOM LCC Model. Complete definitions of all FORTRAN variables appearing above will be found in the Glossary, along with identification of the responsible authority or source of numerical data for input variables.

In the FORTRAN program, SITELCC, for the AFSATCOM LCC Model, the three-dimensional entities FAIL(I,K,NS) and ERHB(I,K,NS) are actually computed as scalars and summed on the index K into a two-dimensional array indexed by I and NS, prior to multiplication by A(I,L). Similarly, ERHD(I,K) is computed as a scalar and summed on K, prior to multiplication by A(I,L). A further feature of SITELCC

is achievement of efficiency in the summations involving A(I,L) multiplications by initializing the arrays ERHAB(L,NS) and ERHAD(L) at zero, then selectively summing the appropriate components of the right-hand sides if and only if A(I,L)=1. Due to the relative sparsity, i.e., large number of zero entries, that the matrix [A(I,L)] would possess if stored in standard matrix form, a "pointer matrix" implementation is utilized in SITELCC. Thus the data is input and stored in vectors of varying lengths, each vector containing nonzero entries only. See Appendix A, Exhibit 7, Table 9: "LRU-SE Usage Matrix (A)" for an example of the input format involved.

It should be noted that in the above calculations of numbers of SE items purchased, NAPB(L,NS) and NAPD(L), two assumptions have been imposed: First, that the SE items are dedicated to the appropriate LRUs undergoing repair, for the entire duration RT(I)*BMF (at base) or RT(I)*DMF (at depot) of the repair operation, and second, that the SE items do not constitute bottlenecks in the sequence of repair operations, or equivalently, that the sequence of LRU types which fail successively is well distributed among the applicable SE items involved. Although the lifting of these two assumptions would require further model refinement and the need for additional statistical inputs, it is readily noted that the effects of the two assumptions tend to cancel each other; imposing the first assumption increases somewhat the number of SE items purchased, whereas imposing the second assumption tends to decrease that number.

Note that the ratios ERHAB(L,NS)/BAA and ERHAD(L)/DAA can be interpreted as the fraction utilization of SE item L at base NS and depot repair shops which possess precisely one such SE item. Thus any such ratio taking a value less than one reveals an item utilized less than full time at the designated site (base NS or depot). A value greater than one establishes that one item will not be sufficient at that site. These ratios can be of independent interest in logistics support studies involving the sharing of facilities with programs other than AFSATCOM. It must be emphasized that the AFSATCOM LCC Model computes utilization of support equipment as needed by the AFSATCOM system only.

If a maintenance bench set is to be installed at base NS, then special AFSATCOM support equipment need not necessarily be purchased for that base. This decision is carried in the coding and assignment of the six available maintenance bench set types, NHM(NS). (See Cost Element 3.) When a maintenance bench set type

which precludes the purchase of special AFSATCOM support equipment is assigned to base NS, then NAPB(L,NS) is set to zero for the appropriate SERD item numbers L which are involved.

The actual unit price CA(L) of SE item L is typically dependent upon the total quantity of that item to be purchased:

$$NAPH(L) = \sum_{NS} NAPB(L,NS) + NAPD(L).$$

The model currently allows for as many as four price categories, defined by user implementation of as many as three price breakpoints; provision for additional price breakpoints could easily be incorporated.

The added-on fraction for maintenance over the life cycle, represented above as PIUP*AMA(L), is actually programmed as DFC(A,B,R)*AMA(L) with A=0, B=PIUP and R the annual interest rate. The function DFC(A,B,R) is the same continuous discount factor as discussed previously for Cost Element 4. Using R=0, the multiplier PIUP results. For R≠0, an annual interest rate must be used.

An earlier version of the AFSATCOM LCC Model used the following equation for Cost Element 7:

$$SC(7) = \sum_{L}\sum_{K}\sum_{I}\left[\sum_{NS} \frac{ERHB(I,K,NS)}{ERHAB(L,NS)} * NAPB(L,NS) + \frac{ERHD(I,K)}{ERHAD(L)} * NAPD(L)\right] * CA(L)*A(I,L)*(1 + PIUP*AMA(L)).$$

This equation not only described the cost of all SE purchased at each maintenance facility (base and depot), plus an allowance for the maintaining of the SE itself, but also prorated a fair share of this cost to each LRU type and to each terminal type, depending upon their expected utilization of the SE items. The factors

$$\frac{ERHB(I,K,NS)}{ERHAB(L,NS)} \quad \text{and} \quad \frac{ERHD(I,K)}{ERHAD(L)}$$

were used to prorate the cost of SERD item L to LRU type I and terminal type K, at base NS and at the depot, respectively.

By using this equation, it was possible in the earlier version of the AFSATCOM LCC Model to break down Cost Element 7 according to LRU type or terminal type. That portion of Cost Element 7 attributable to LRU type I was calculated with the summation on I omitted. That portion of Cost Element 7 attributable to terminal type K was calculated with the summation on K omitted.

2.1.8 Cost Element 8 (Initial Training)

Cost Element 8 is the cost of initial training, i.e., the costs to train the initial maintenance and operator/specialist personnel, and the cost of specific training equipment required for the system. To compute these costs, the LRU types are grouped into categories for training purposes; it is anticipated that within a category all LRU types are to be repaired at the same level (i.e., base repair or depot repair).

This cost of initial training is computed as follows:

$$SC(8) = TE + TOPI + \sum_{M} [NMTB*RTS1(M) + NMTD*NRTS1(M)] *(TCMW + PAL)*TW(M)$$

where TE is the cost of training equipment required, TOPI is the cost of initial training of organizational-level maintenance and operator/specialist personnel, and the summation expression is the cost of initial contractor-provided training for base and depot maintenance personnel (including instruction and training materials).

Within the summation expression above, NMTB is the number of men trained for base level maintenance work, NMTD is the number of men trained for depot level maintenance work, RTS1(M) and NRTS1(M) are normalizations of RTS(I) and NRTS(I) for category M containing LRU

type I (see below), and TCMW and PAL are respectively, the average cost of initial contractor-provided training, and the student pay and allowances for average grade trained. Both TCMW and PAL are in dollars per man per week, and TW(M) is the average number of weeks needed to train a man to repair any LRU type in category M.

The number of men trained for base level maintenance work, NMTB, is the sum over all bases NS of the number of men trained for such maintenance work at base NS, NMT(NS):

$$NMTB = \sum_{NS} NMT(NS).$$

The components NMT(NS) and NMTD are computed from more basic inputs:

$$NMT(NS) = \text{Max} \{ MMTB(NS), [NPERB(NS)]^{+} \}$$

$$NMTD = \text{Max} \{ MMTD, [NPERD]^{+} \}$$

where $[\ldots]^{+}$ denotes rounding up to the next higher integer, MMTB(NS) and MMTD are the minimum number of men planned for initial training to support AFSATCOM at base NS and at the depot respectively, and NPERB(NS), NPERD are the fraction utilization of a one-man shop at base NS and at the depot, respectively. These fraction utilizations are computed as ratios of required repair time to available repair time,

$$NPERB(NS) = ERPSB(NS)/BAA$$

$$NPERD = ERPSD/DAA$$

where ERPSB(NS), ERPSD represent the expected repair time required in man-hours/month at base NS and at the depot, respectively (with expected base repair time including remove and replace time),

$$ERPSB(NS) = \sum_{K}\sum_{I} FAIL(I,K,NS)*(RTS(I)*RT(I)*BMF*KB + RMH(I))$$

$$ERPSD = \sum_{NS}\sum_{K}\sum_{I} FAIL(I,K,NS)*NRTS(I)*RT(I)*DMF*KD,$$

and BAA, DAA are the total available active work time in hours/month at base, depot repair shops. (Thus BAA, DAA represent total available man-hours/month at hypothetical one-man shops.)

The fraction utilizations NPERB(NS) and NPERD are of independent interest. Any such variable taking a value less than one reveals a site (base or depot) at which the repair shop experiences less than full-time utilization of one man; a value greater than one establishes that one man will not be sufficient at that site. These data play a role in logistics support studies involving facilities and personnel to be shared with programs other than AFSATCOM. It must be emphasized that the AFSATCOM LCC Model computes utilization of repair shop facilities and personnel as needed by the AFSATCOM system only.

The normalizations RTS1(M) and NRTS1(M) in the summation expression of the equation for Cost Element 8 are to convert RTS(I) and NRTS(I) into zero-one variables (see Exhibit 3)

$$RTS1(M) = U(RTS(I))$$

$$NRTS1(M) = U(NRTS(I) - NRT)$$

for category M containing LRU type I. The function U(X) used above is a unit step function for strictly positive X,

$$\begin{aligned} U(X) &= 1 \quad \text{if } X > 0 \\ &= 0 \quad \text{if } X \leq 0. \end{aligned}$$

In the actual FORTRAN program of the AFSATCOM LCC Model, SITELCC, the assignment of LRU type I into category M is effected by the manner in which TW(M) input data is prepared. Actually, the program sums on index I, not M, but TW(I) is input as zero for all

but one LRU type in each category; the nonzero TW(I) then serves as TW(M). Also, in the actual FORTRAN program, the three-dimensional entity FAIL(I,K,NS) is computed as a scalar and summed on the indices I and K into ERPSB(NS) and ERPSD.

2.1.9 Cost Element 9 (Recurring Training)

Cost Element 9 is the cost of recurring training, i.e., the cost to train the maintenance and operator/specialist personnel required to replace the initially trained personnel who have been promoted, transferred, or have left the Air Force.

This cost of recurring training is computed as follows:

$$SC(9) = [TOPR + \sum_{NS} NMT(NS)*TRB(NS)*TCMB + NMTD*TRD*TCMD]*(PIUP-1)$$

where TOPR is the annual cost of replenishment training of organizational level maintenance and operator/specialist personnel, TRB(NS) and TRD are the additional fraction of men at base NS and at the depot, respectively, which must be trained annually to fill maintenance personnel vacancies, and TCMB, TCMD are the average per-man costs of training courses for base-level maintenance and depot-level maintenance, respectively (including instruction and training materials).

Note that the equation for Cost Element 9 is based on personnel being trained by the Air Training Command at a per-man course rate, whereas the equation for Cost Element 8 used a weekly dollar rate per man.

The factor (PIUP-1) assumes that recurrent training starts up in the second year of the AFSATCOM system operation, and is held at uniform levels throughout the remaining life of the system.

The factor (PIUP-1) is actually programmed as DFC(A,B,R) with A=1, B=PIUP and R the annual interest rate. The function DFC(A,B,R) is the same continuous discount factor as discussed previously for Cost Element 4. Using R=0, the factor (PIUP-1) results. For R≠0, an annual interest rate must be used.

2.1.10 Cost Element 10 (New Item Inventory Management)

This cost element accounts for the management (administrative) cost to introduce new assemblies and parts into the Air Force inventory system, and the recurring supply inventory management costs associated with such inventories. It is assumed that the first year's inventory system set-up costs plus inventory management costs equals the annual inventory management cost for each remaining year; current AFSATCOM cost accounting procedures support this assumption.

The equation for this cost element is

$$SC(10) = PIUP * \sum_{I} [NLRU(I)*(1 + CPA(I))*IMC + (NIS(I) + NCIS(I)*CPA(I))*SA]$$

where NLRU(I) is an indicator (or flag) variable which is one if LRU type I is utilized at some base in the current AFSATCOM LCC Model run (implying that this LRU type is a new item in the Air Force inventory system), zero otherwise; CPA(I) is the number of new "P"-coded assemblies (SRUs) added to the AF inventory system to support repair of LRUs of type I; IMC is the annual inventory management cost incurred due to introduction of a new "P"-coded item; NIS(I) is the number of bases which use LRU type I; NCIS(I) is the number of bases which stock SRUs to support base level repair of LRUs of type I; SA is the annual supply inventory management cost per base.

Four of the above variables are computed from more basic inputs:

$$NLRU(I) = U\left(\sum_{NS} \sum_{K} QPA(I,K)*IT(K,NS) \right)$$

$$CPA(I) = PA(I)*U(1 - COND(I))$$

$$NIS(I) = \sum_{NS} U\left(\sum_{K} QPA(I,K)*IT(K,NS) \right)$$

$$NCIS(I) = \sum_{NS} U\left(\sum_{K} QPA(I,K)*IT(K,NS)*RTS(I) \right)$$

where U(X) is a unit step function for strictly positive X,

$$\begin{aligned} U(X) &= 1 \quad \text{if } X > 0 \\ &= 0 \quad \text{if } X \le 0. \end{aligned}$$

Complete definitions of all FORTRAN variables which appear above can be found in the Glossary.

<u>Note</u>: Equivalent computational procedures for NLRU(I) and NIS(I), using definitions given in Appendix B, "Quantities of LRUs," below, are

$$\begin{aligned} NLRU(I) &= U(QLRU1(I)) \\ &= U\left(\sum_{NS} QLB1(I,NS) \right) \end{aligned}$$

$$NIS(I) = \sum_{NS} U(QLB1(I,NS))$$

from which it can be shown that

$$NLRU(I) = U(NIS(I)).$$

The distinction between CPA(I) and PA(I) is as follows: PA(I) is provided by the contractor in advance of using an ORLA Routine [3] to decide whether LRUs of type I are to be repaired or condemned

upon failure (see the discussion in Cost Element 4, and Exhibit 3, on variables evaluated via ORLA; see also the Glossary) whereas CPA(I) equals PA(I) if LRU type I is to be repaired, equals zero if LRU type I is to be condemned.

The multiplier PIUP in the equation for Cost Element 10 is actually programmed as DFC(A,B,R) with A=0, B=PIUP and R the annual interest rate. The function DFC(A,B,R) is the same continuous discount factor as discussed previously for Cost Element 4. Using R=0, the multiplier PIUP results. For R≠0, an <u>annual</u> interest rate must be used.

2.1.11 Cost Element 11 (Technical Data)

The following equation describes the cost of technical data, i.e., the cost of purchasing the master negatives for Technical Orders, overhaul manuals and other special technical documentation or repair instructions:

$$SC(11) = [TDSP + \sum_{I} TDLP(I) + \sum_{K} TDTP(K) + \sum_{L} TDAP(L)]$$

$$*[ACPP + TDP + TDU*(PIUP-1)].$$

Detailed definitions and units of all these FORTRAN variables are given in the Glossary, along with identification of the responsible authority or source of numerical data for input variables. Briefly, the first expression in parentheses counts the number of pages, and the second expression in parentheses contains the acquisition costs per page and the upkeep cost per page per year multiplied by (PIUP-1), which assumes that new document acquisition provides for the first year and upkeep costs provide for the remainder of the life cycle.

The factor (PIUP-1) is actually programmed as DFC(A,B,R) with A=1, B=PIUP and R the annual interest rate. The function DFC(A,B,R) is the same continuous discount factor as discussed previously for Cost Element 4. Using R=0, the factor (PIUP-1) results. For R≠0, an <u>annual</u> interest rate must be used.

2.1.12 Outputs of the LCC Routine (Summary)

The LCC Routine displays as AFSATCOM LCC Model output the total system life cycle cost, defined as the sum of the eleven cost elements described above. For each of these cost elements, the cost over the life cycle is output, both in dollars and as a percentage of total life cycle cost. Also output is the apportionment of total life cycle cost, and of each cost element, into acquisition cost and/or operation and support cost. Where possible by the equation structure of the model, certain cost elements are further broken down by LRU type and/or by terminal type.

The printed outputs of the AFSATCOM LCC Model include not only cost information, but also a display of a large number of non-cost variables computed in the LCC Routine and in the Sparing and Availability Routines to be discussed below. A complete description of the output reports of the AFSATCOM LCC Model, with illustration of a set of actual reports from a sample model run, is included as Appendix A of this document.

2.2 The Sparing Routine

2.2.1 Overview

The Sparing Routine, called EBOS (for Expected Backorder Sparing), decides for each LRU type and at each base whether an inventory of that LRU type is to be maintained to support the operation of AFSATCOM terminals at that base. A similar decision is made by the Sparing Routine for each LRU type at the depot. For each case where an inventory is to be maintained, the Sparing Routine computes the appropriate quantity of spares to be acquired. The criterion employed for determining the size of inventory, if any, is that such inventory is to consist of the minimum quantity of spares of each LRU type needed at each base or at the depot in order to guarantee that the average number of LRUs on backorder each month (i.e., LRU failures which place a terminal into NORS condition* after depletion of base inventory) is no more than a preassigned upper limit. This limit is controllable by the user of the model to achieve tradeoff between cost of LRU inventories and availability of terminals. For AFSATCOM analyses, the preassigned upper limit has been taken at 0.1 backorders per month for each LRU type, at each base and at the depot. This is consistent with current AFLC use of the Logistics Support Cost (LSC) Model (Reference [1]). It is to be

*Not operationally ready due to supply.

noted, however, that the Sparing Routine could be employed with these preassigned upper limits dependent upon LRU type and specific base, or depot. Such a feature allows the AFSATCOM LCC Model to be of use in finer studies involving the tradeoff between the cost of LRU inventories and the availability of AFSATCOM terminals.

The Sparing Routine allows for the possibility that transportation and/or repair can be expedited for LRU failures which occur while the base inventory is depleted, i.e., failures which place a terminal into NORS condition.

The expected number of backorders per month allowable for each LRU at a given base and at the depot will affect the availability of the terminals at that base. The computations for LRU sparing and for terminal availability both require consideration of which LRUs are used in which terminals, and the average operating hours per month of these terminals at the base in question. However, in LRU sparing, the LRU type is held fixed while all terminal types at that base are considered, whereas when computing terminal availability the terminal type is held fixed while all LRU types within that terminal are considered. Terminal availability calculations are performed by the Availability Routine to be discussed in Section 2.3 below.

In addition to calculating the quantity of spares for base and depot inventories, the Sparing Routine also calculates the expected number of backorders per month and the probability of backordering (i.e., of needing replacements <u>after</u> inventory has been depleted) at the bases and at the depot, for the computed quantity of spares. The quantity of spares calculated by this routine is an input to the AFSATCOM LCC Routine (in particular, to Cost Element 2 of Section 2.1 above), and the resulting probability of backordering will be an input to the Availability Routine (Section 2.3 below).

The same Sparing Routine is used to compute the quantity of spares, expected number of backorders per month, and probability of backordering, at the depot as well as at the various bases. This is accomplished by a change of input data to the routine and does not require any change in the routine itself.

In SITELCC, the FORTRAN program for the AFSATCOM LCC Model, Subroutine EBOS is called from the LCC Routine. As such, the variable names used in the calling routine need <u>not</u> be identical with the names of the same variables in the subroutine. Exhibit 4 lists the Subroutine EBOS variables which transfer through the

calling procedure, and displays the correspondence between variable names in the subroutine and in the calling routine for the two situations of interest: LRUs of type I at base NS, and LRUs of type I at the depot. In addition, Exhibit 4 notes the routine to which each EBOS output variable is transferred. The quantities SB(I,NS) and SD(I), namely, the internally-computed sparing levels for each LRU type at each base and at the depot, also appear among the output reports of the AFSATCOM LCC Model (see Appendix A).

The structure for developing the Sparing Routine is as follows: For each given LRU type I at given base NS, a failure rate (average number of failed LRUs per month) is computed as a composite of the individual failure rates of LRUs of that type at that base. Each failed LRU is replaced in the terminal by a similar type LRU from base inventory (if any) and is submitted into a "generalized base/depot pipeline" which includes the time durations and associated probabilities of base repair, depot inventory, depot repair, and appropriate transportation time, for the given indices I and NS. The average pipeline time multiplied by the LRU failure rate, termed the "load factor," AS, is computed for the LRU type I and base NS.

The pipeline is now viewed as an infinite-channel (i.e., infinite-server) queuing system, where the number of customers in the system is the number of LRUs of type I from base NS which are simultaneously undergoing some form of pipeline service. From this viewpoint the load factor AS is seen to be precisely the average number of LRUs in the pipeline, and the probability distribution of the number in the pipeline is obtained.

Let QS denote the quantity of spares of LRU type I to be acquired for inventory at base NS. Then whenever there are QS or less LRUs in the pipeline, the base inventory will suffice to keep all AFSATCOM terminals operating. However, when the number in the pipeline exceeds QS, then the excess will be a count of the number of backorders of LRU type I at base NS. With probabilities of each such event having been obtained via the infinite-channel queuing system analysis, the expected number of backorders, EBO, of LRU type I at base NS is computed. If this number is less than or equal to the preassigned upper limit AX, the Sparing Routine ends; otherwise, QS is increased by one and the procedure is repeated. As QS increases, EBO decreases to zero, hence for any positive AX the Sparing Routine terminates at the desired level of QS.

	Name of Variable in Subroutine EBOS	Name of Variable in Calling Routine		Routine to Which EBOS Output Variable is Transferred
		for LRU Type I at Base NS	for LRU Type I at the Depot	
Inputs:				
Load Factor	AS	AB(I,NS)	AD(I)	
Upper Limit for Expected Backorders	AX	EBO	EBO	
Expediting Factor	EXF	EXF(I,NS)	(set to 1.0)	
Outputs:				
Quantity of Spares to be Acquired	QS	SB(I,NS)	SD(I)	LCC Routine
Expected Number of Backorders	EBO	(dummy name)	(dummy name)	(not used)
Probability of Backordering	PC	PCB(I, NS)	PCD(I)	Availability Routine

Exhibit 4. Correspondence Between Names of Variables in Subroutine EBOS and in Calling Routine, and Identification of Routine to Which Each EBOS Output Variable is Transferred

2.2.2 Inputs

The inputs to the Sparing Routine are the load factor, AS, the upper limit on expected number of backorders per month, AX, and the expediting factor EXF by which pipeline time is divided whenever inventory is depleted.

Load factor AS is the LRU failure rate (per month) multiplied by the average pipeline time (in months). When the Sparing Routine is used to obtain base inventory, AS is set up from base parameters; if the Sparing Routine is to compute depot inventory, then depot parameters must yield AS.

2.2.2.1 Load Factor for Base Inventory: For each given LRU type I at a given base NS, base inventory is obtained by calling the Sparing Routine with load factor AS computed in advance as

```
AB(I,NS) = XFB(I,NS)
           *[RTS(I)*BRCT*KB + (NRTS(I)*KD + COND(I))*OST(LO(NS))].
```

Here XFB(I,NS) represents the expected number of removals per month of LRU type I at base NS,

$$XFB(I,NS) = \sum_{K} FAIL(I,K,NS),$$

where FAIL(I,K,NS) is the expected number of removals per month of LRU type I in terminal type K at base NS; as in Section 2.1,

```
FAIL(I,K,NS) = QPA(I,K)*IT(K,NS)*(1-RIP(I))*ATOH(K,NS)
               *MFAC(LE(K))/MOTBMA(I,LE(K)).
```

The expression in brackets above, [RTS(I)*BRCT*KB + ...], represents the average pipeline time of a "generalized base/depot pipeline."

All FORTRAN variables which appear above are defined in the Glossary. Briefly, the monthly failure rate of an LRU type by base is a sum of the failure rates for that LRU type by terminal type as

well as by base, allowing that not all of the maintenance actions of LRUs result in removal and insertion into the pipeline, that average operating time per month varies with the terminal type, and that both predicted and operational mean operating time between maintenance actions are functions of the environment of the terminal (i.e., ground fixed, ground transportable, or airborne). The average pipeline time (in brackets, above) is composed of three components: a first component due to LRUs of the specified type which are repaired at the base, another due to LRUs repaired or replaced at the depot, and a third for LRUs condemned upon failure. Since the second and third components both involve depot-to-base transportation time, the location LO(NS) of the base (continental U.S. or overseas) is considered.

RTS(I) is the fraction of removals of LRUs of type I which are expected to be repaired at the base, NRTS(I) is the fraction of such removals expected to be returned to the depot for repair, and COND(I) is the fraction expected to be condemned upon failure. Respectively with these coefficients, BRCT is the average base repair cycle time until the failed LRU is repaired and capable of returning to base inventory (with the multiplier KB converting FAIL(I,K,NS) from expected number of removals per month to expected number of failures per month), OST(LO(NS)) accounts for the order and one-way shipping time from depot to base of a new LRU to replenish base inventory while the failed LRU undergoes repair at the depot (the multiplier KD converting FAIL(I,K,NS) from removals departing the base to repaired LRUs returning to the base from the depot), and the coefficient of COND(I) is the same as for NRTS(I) (but with the multiplier KD omitted).

The formula for average pipeline time is based upon negligible probability of the depot inventory being depleted. To see this, consider the more exact expression for the component of formula due to repair/replacement at the depot (FORTRAN indices omitted for brevity)

NRTS*KD*[(1-PCD)*OST + PCD*OSTX]

where PCD is the probability of depot inventory being depleted. In such case, the order and one-way shipping time OST from depot to base must be replaced by an expedited order and two-way shipping time plus depot repair and handling time, say OSTX. For PCD

negligible, this expression reduces to NRTS*KD*OST as first presented.

2.2.2.2 Load Factor for Depot Inventory: For each given LRU type I, depot inventory is obtained by calling the Sparing Routine with load factor AS computed in advance as

$$AD(I) = \sum_K XF(I,K)*(1-RTS(I))*DRCT \quad \text{if} \quad COND(I) < 1,$$

$$= 0 \quad \text{if} \quad COND(I) = 1.$$

Here $\sum$ XF(I,K) represents the expected number of removals (failures) per month of LRU type I at all bases, where

$$XF(I,K) = \sum_{NS} FAIL(I,K,NS),$$

the factor 1-RTS(I) reflects the fact that not all such failures are replenished by depot inventory or repair, and DRCT is an average of the depot's own pipeline time for all LRU types and base locations: one-way shipping time to receive the failed LRU, plus depot handling and repair time.

For LRU types I such that COND(I)=1, a load factor of zero is input to the Sparing Routine; this causes an output of QS=0, namely, no depot inventory based upon depot pipeline time for LRU types condemned upon failure. Actually, the AFSATCOM LCC Model does account for the cost of replacements for LRUs condemned upon failure. This cost is accounted for in the LCC Routine, Cost Element 5, namely, the cost of replacement LRUs and SRUs over the life cycle PIUP. Specifically, the cost of such replacement LRUs is included in that cost element via the use of the product COND(I)*UC(I) where UC(I) is the unit cost of an LRU of type I. (See Cost Element 5 in Section 2.1.) To account for these replacements in the depot sparing term of Cost Element 2, spares acquisition, would be a double counting of their costs; hence, when establishing depot inventory levels, the output QS of the Sparing Routine (which returns to Cost Element 2 as per Exhibit 4 above) must be zero for LRUs condemned upon failure.

2.2.2.3 Upper Limit for Expected Backorders: The input AX is a preassigned upper limit on the expected number of backorders per month to be calculated by the Sparing Routine. As this routine is currently used in the AFSATCOM LCC Model, AX is taken at 0.1 backorders per month. This is consistent with current AFLC procedures (see discussion in "Overview," Section 2.2.1, above). It is to be noted that the Sparing Routine could be employed with AX dependent upon LRU type and specific base or depot.

In SITELCC, the FORTRAN program for the AFSATCOM LCC Model, Subroutine EBOS is called from the LCC Routine. As such, the variable names used in the calling routine need not be identical with the names of the same variables in the subroutine. To conform to the terminology of the documentation for the AFLC Logistics Support Cost (LSC) Model (Reference [1]), the upper limit for expected backorders is input as EBO in the main program, and received as AX in the subroutine. This use of the variable name "EBO" must not be confused with the EBO discussed thus far, and to be discussed further in Subsections 2.2.4 and 2.2.4.2, entitled "Outputs" and "Expected Number of Backorders," below. See Exhibit 4 for clarification and additional information.

2.2.2.4 Expediting Factor: An expediting factor EXF is provided as an input to allow that transportation and/or repair can be expedited for failures which occur while inventory is depleted. The Sparing Routine uses the load factor AS while failures decrease the inventory to zero. Whenever inventory is already depleted, failures are given the load factor AS divided by EXF, representing pipeline time divided by EXF. If expediting is to be utilized, EXF input must be greater than one. Otherwise, input EXF = 1. (The expediting factor is used in the calculation of the probability of backordering, PC, but not in the calculation of the quantity of spares QS. Details and rationale are presented in the "Outputs" subsection, below.)

In SITELCC, the FORTRAN program for the AFSATCOM LCC Model, the user's control over whether or not expediting is to be employed is exercised via the control variable NEXF. Setting NEXF=0 causes EXF to be calculated in the calling procedure for Subroutine EBOS as

$$EXF(I,NS) = \frac{[RTS(I)*BRCT + (1-RTS(I))*OST(LO(NS))]*730}{\left[\begin{array}{l} TRANB(IBS(I)) + RTS(I)*RT(I)*BMF \\ \qquad + (1-RTS(I))*TRAND(LO(NS)) \end{array}\right]}$$

for computation of PCB(I,NS), the probability of backordering for LRU type I at base NS. Setting NEXF=1 causes

EXF(I,NS)=1.0,

the default value for no expediting. Regardless of the control NEXF, the expediting factor EXF=1.0 is always input when calling Subroutine EBOS for computation of PCD(I), the probability of backordering LRU type I at the depot, since in this case "expediting" would imply "expedited depot repair", which is not modeled.

Note that in the numerator of EXF(I,NS), when NEXF=0, the expression in brackets is precisely the ratio AB(I,NS)/XFB(I,NS) presented and explained above in Subsection 2.2.2.1, "Load Factor for Base Inventory," but without the multipliers KB or KD, since

NRTS(I) + COND(I) = 1 - RTS(I).

The multiplier 730 converts months, the units of the numerator, into hours, the units of the denominator, since the expediting factor must be dimensionless. An explanation of the denominator of EXF(I,NS) follows somewhat the rationale for that of the numerator: Whether or not the LRU type is coded for base repair, the transportation time TRANB(IBS(I)) associated with on-base delivery of a replacement LRU of type I, from base supply location IBS(I), must elapse. For the fraction RTS(I) expected to be repaired at the base, when base inventory is depleted the base repair time RT(I)*BMF is incurred. For the remaining fraction (1-RTS(I)), the time incurred is TRAND(LO(NS)), the transportation time associated with shipment of a replacement LRU from the depot to base NS, via an expedited priority, where LO(NS) denotes base location (continental U.S. or overseas).

2.2.3 Development of Steady-State Probabilities

The following discussion develops the steady-state probability distribution of the number of LRUs of the specified type in the pipeline. If the Sparing Routine is to establish inventory at a specified base, then the pipeline includes both base and depot handling, repair, and transportation times (weighted with their associated probabilities of base or depot action). If the Sparing Routine is employed for calculating depot inventory, then the pipeline is comprised only of average shipping plus depot handling and repair times. Steady-state probabilities have the following interpretation: After an initial transient behavior due to start-up, the steady-state probability p_n is the probability that there are n LRUs in the pipeline either at a random point in time or at the end of each month.

The pipeline is now viewed as an infinite-channel queuing system, where the "customers" are the requests for replacements of failed LRUs (or are the failed LRUs themselves in cases when it is not possible to exchange new LRUs for failed LRUs), the customers' interarrival times are the times between failures of the specified type LRU, and service time is pipeline time. Hence the number of customers in the system is the number of LRUs of the specified type which are simultaneously undergoing some form of pipeline service. The infinite-channel assumption, that the number of customers being served does not have a specified upper bound, is reasonable in light of the application to AFSATCOM.

For the case of no expediting, EXF=1, the following result is well-known [5]: If the process of arrivals to an infinite-channel queuing system constitute a Poisson process with rate λ customers per unit time (i.e., independent interarrival times with a common exponential distribution, mean interarrival time $1/\lambda$) and the service times are independent of the arrival process and of the number currently

being served, then regardless of the probability distribution of the service times, the steady-state probabilities are Poisson with mean λT where T is the mean service time. Thus

$$p_n = \frac{e^{-\lambda T}(\lambda T)^n}{n!}, \quad n = 0, 1, 2, \cdots. \tag{1}$$

Note that the product λT is the load factor AS input to the Sparing Routine, and is the average number of LRUs in the pipeline.

It will be of interest to note that (1) is identical with the following standard result for birth-death processes (or for the queuing system described above but with exponentially-distributed services times) [5], Chapter 3:

$$p_n = \frac{\lambda_0\lambda_1\cdots\lambda_{n-1}}{\mu_1\mu_2\cdots\mu_n} p_0, \quad \sum_{n=0}^{\infty} p_n=1 \tag{2}$$

with arrival rates

$$\lambda_0=\lambda_1=\cdots=\lambda_{n-1}=\lambda$$

and service rate for state n (combination of n individual service rates)

$$\mu_n=n\mu, \quad \mu=1/T.$$

For the case with expediting, EXF>1, Sherbrooke [6] has established a general theorem from which p_n can be obtained. For the purpose of this discussion, Sherbrooke's result may be presented in the following more specialized form: If the process of arrivals to an

infinite-channel queuing system constitute a Poisson process with rate λ_n when n customers are in the system, and the service times are independent of the arrival process, with service rate μ_n when n customers are in the system, then regardless of the probability distribution of the service times, the steady-state probability distribution satisfies (2).

We now define what we mean by expediting, in the notation of (2). We assume that expediting occurs only when there are backorders, i.e., when inventory is depleted and subsequent failures place AFSATCOM terminals into NORS condition. For each customer which arrives while inventory is depleted, we divide that customer's service time by EXF, the expediting factor. This is equivalent to multiplying that customer's service rate by EXF, so that

$$\mu_n = n\mu = n/T \quad \text{for } n \leq QS$$

$$\begin{aligned}\mu_n &= (QS)\mu + (QS-n)\mu' \\ &= (QS)/T + (QS-n)(EXF)/T \quad \text{for } n > QS\end{aligned}$$

where μ' is the expedited service rate, and in the FORTRAN notation of the Sparing Routine, QS is the quantity of spares in inventory, EXF is the expediting factor. Thus the steady-state probabilities of (2) are

$$P_n = \frac{(\lambda T)^n}{n!} P_0 \qquad \text{for } n \leq QS$$

$$P_n = \frac{(\lambda T)^n}{(QS)! \prod_{m=1}^{n-QS} (QS + m(EXF))} P_0 \qquad \text{for } n > QS \qquad (3)$$

with

$$p_0 = 1 - \sum_{n=1}^{\infty} p_n$$

The above equation (3) represents the case where expediting is put only to failed LRUs for which an AFSATCOM terminal has been placed in NORS condition. The logistics support system for AFSATCOM is expected to operate in this manner; replacements ordered from depot inventory as back-up to base inventory will be shipped at routine priority, whereas replacements ordered to return a NORS terminal to operational condition will be delivered to the base on a higher priority (usually via airlift). In this regard, it should be noted that the form of expediting employed in [6] was to speed up all service in progress on items in the pipeline, whenever a NORS (backorder) condition exists. Such interpretation of expediting results in the following modification of (3):

$$p_n = \frac{(\lambda T)^n}{(QS)!(EXF)^{n-QS}} \qquad \text{for } n>QS \qquad (4)$$

The Sparing Routine can be modified so as to represent the expediting mode of (4) rather than that of (3). However, in any logistics system for which immediate resupply is by depot inventory rather than by depot repair and return, with the depot serving more than one base, it is doubtful that delivery of all items requested earlier by a given base can be expedited beginning at that later point in time when the base experiences its first backorder.

The use of (2) with $\lambda_0 = \lambda_1 = \cdots$ (arrival rate of customers independent of number in pipeline) represents the assumption of an infinite population. Sherbrooke [6] notes that the infinite population assumption is appropriate for an aircraft application because the

programmed flying hours are allocated to the operational aircraft regardless of the number of NORS aircraft (within limits, of course). By contrast, in a missile application with a finite population of N alert missiles, it would probably be appropriate to set $\lambda_m = (N-m)\lambda$ for $0 \leq m < N$, and $\lambda_m = 0$ otherwise [6].

The Sparing Routine employs the infinite population assumption in calculation of steady-state probabilities. As applied to the AFSATCOM system, this is an assumption that LRU failure rates are independent of the number of LRUs in the pipeline, including in particular the assumption that LRU failure rates do not decrease as the number of AFSATCOM terminals in NORS condition increases. This assumption has two justifications: First, on bases which utilize a large number of airborne AFSATCOM terminals of a single kind, the mission objectives are allocated to the operational terminals regardless of the number of NORS terminals (within limits, of course). Second, each terminal has a "prime mission" objective which can be performed with less than full operational capability. Hence the loss of an LRU from a terminal need not result in that terminal being shut down. (In this regard, it should be noted that "prime mission" capability is protected by a degree of redundancy in the functions of LRUs within terminals.)

In general, it is to be noted that the accuracy of an infinite population approximation improves as the upper limit on expected number of backorders, AX, decreases. This is so because a decrease in backorders (with its associated increase in base inventory) yields a decrease in the rate at which NORS terminals occur; the case of no NORS terminals corresponds (in LRU failure rate) to the case of infinite population.

2.2.4 Outputs

The outputs calculated by the Sparing Routine are QS, the quantity of spares to be acquired for initial inventory, EBO, the expected number of backorders which result when the system is in steady-state, and PC, the steady-state probability of backordering, i.e., of needing one or more spares for replacement after inventory has been depleted. (Hence, for a given LRU type I at a given base NS, PC is the probability of at least one NORS terminal at that base, awaiting arrival of that LRU type.) The method of computing each of these outputs is discussed below.

Since the Sparing Routine is programmed to be the same for both base and depot sparing, the interpretation of outputs is a function of the use of this routine as established by its calling procedure. Thus QS, quantity of spares to be acquired, may pass to the LCC Routine, Cost Element 2, as either base sparing or depot sparing. Similarly, PC may pass to the Availability Routine (Section 2.3 below) as the probability of LRU type I inventory being depleted at a base or at the depot. (See Exhibit 4.)

2.2.4.1 Quantity of Spares to be Acquired: If the load factor, AS, is sufficiently small (less than 5×10^{-5}), the Routine returns QS = 0. If the load factor is sufficiently large, then the Routine returns QS equal to the mean plus $\sqrt{3}$ times the standard deviation of the number of items in the pipeline. Since the standard deviation of a Poisson distribution is the square root of its mean, this procedure is in accordance with published USAF methods [7].

For AS between the sufficiently small and sufficiently large thresholds given above, an iterative procedure is used such that QS is the smallest number satisfying the condition that

$$\sum_{n=QS}^{\infty} (n-QS)p_n \leq AX, \qquad (5)$$

where p_n is the steady-state probability of n items in the pipeline, using λT=AS. (Note that the summation expression of (5), which is upper-bounded by AX, is the expected number of backorders for acquired inventory QS.)

The iteration procedure is to increase QS by one if the above condition (5) is not yet met. Computation time is saved by recognizing that QS must increase to at least AS-AX, since

$$AX \geq \sum_{n=QS}^{\infty} (n-QS)p_n \geq \sum_{n=0}^{\infty} (n-QS)p_n$$

$$= AS - QS.$$

Thus

$$QS \geq AS - AX.$$

In addition, QS is restricted to be at least one if the mean pipeline time is more than one percent of the mean inventory cycle time (mean time between demands (arrivals) plus mean pipeline time), i.e., if

$$\frac{T}{\frac{1}{\lambda} + T} = \frac{\lambda T}{1 + \lambda T} = \frac{AS}{1 + AS} > .01$$

As a protection against erroneous inputs, the Sparing Routine terminates the procedure at QS=300 for inputs requiring an output of QS > 300.

2.2.4.2 Expected Number of Backorders: The Sparing Routine calculates EBO based upon the steady-state probability distribution which would result in the absence of expediting,

$$EBO = \sum_{n = QS+1}^{\infty} (n-QS)p_n$$

using the p_n of the non-expedited mode whether or not $EXF > 1$. The rationale for using p_n of the non-expedited mode is as follows: For a given input AS, the probability distribution p_n favors lower numbers of items in pipeline under the expedited mode ($EXF > 1$) than under the non-expedited mode ($EXF=1$). As such, EBO calculated via the probability distribution of the expedited mode would be less than EBO calculated via the probability distribution of the non-expedited mode, so that for the same input AX, a smaller QS would result from the use of expediting. If this smaller QS were output, it would reflect a belief that expediting is the norm rather than the exception, which would not be consistent with the objectives of the support systems for large-scale systems such as AFSATCOM.*

2.2.4.3 Probability of Backordering: The output PC is the sum of the steady-state probabilities

$$PC = \sum_{n = QS+1}^{\infty} p_n$$

where the p_n incorporates expediting if $EXF > 1$. As such, PC is the steady-state probability of needing one or more spares for replacement after inventory has been depleted. Equivalently, PC is the probability of at least one NORS terminal at a random point in time or at the end of each month, for the given LRU type and base or depot.

---

*The additional cost of expediting an LRU to the site of a NORS AFSATCOM terminal, via a higher priority, is not included in life cycle cost as computed by this model.

2.3 The Availability Routine

The AFSATCOM LCC Model includes an Availability Routine which calculates and displays the availability, mean down time (MDT), and mean time between demands (MTBD) of each terminal operating at each base in the AFSATCOM system. A discussion of the display of this information is included in Appendix A. (Formal definitions of MDT and MTBD will be found in the Glossary. The Availability Routine will be abbreviated AVAIL for references in the Glossary.)

Terminal availability is expressed as a ratio of terminal MTBD to terminal regeneration cycle time (MTBD plus MDT). The calculations for terminal MTBD account for terminal utilization by base as well as by terminal type. The MTBD and MDT values are calculated based upon predicted LRU failure rates by LRU type and operating environment (ground fixed, ground transportable, or airborne) of the given terminal containing the LRU.

Terminal MDT is a probability-weighted average over the time to isolate, remove, and replace a failed LRU, assuming all possible inventory conditions and locations. The calculations account for the LRU repair-level designation (base repair, depot repair, or discard), sparing level (set to meet expected backorder requirements), and the time to obtain spares from the next higher maintenance level (assuming expedited handling) if base inventory is depleted.

2.3.1 Terminal Availability

From the modest assumption that (i) the successive up-times of a given terminal of type K at base NS are independent and have a common probability distribution with mean time between demands MTBDT(K,NS), (ii) the succesive down-times of a given terminal of type K at base NS are independent and have a common probability distribution with mean down-time MDT(K,NS), and (iii) the up-times are independent of the down-times, it can be shown (see Reference [8], pp. 42-44) that the limiting probability (after start-up transient behavior has disappeared) of the given terminal being up is the ratio of MTBDT(K,NS) to the sum MTBDT(K,NS) + MDT(K,NS). In the Availability Routine of the AFSATCOM LCC Model, it is this limiting probability which is taken as the "availability" AV(K,NS) for the given terminal of type K at base NS:

$$AV(K,NS) = \frac{MTBDT(K,NS)}{MTBDT(K,NS) + MDT(K,NS)} \qquad \text{if} \quad IT(K,NS) > 0$$

$$= 0 \qquad \text{if} \quad IT(K,NS) = 0.$$

The remainder of the discussion now focuses on the method and underlying assumptions for calculation of MTBDT(K,NS) and MDT(K,NS).

Note that in this discussion there will be no consideration of the actual number of terminals of type K at base NS, IT(K,NS), other than its role in the above equation for availability, i.e., that AV(K,NS)=0 if IT(K,NS)=0 (with similar roles in the equations for mean time between demands and mean down time, to be presented below). As such, AV(K,NS) is the availability of a <u>given</u> terminal of type K at base NS, not the availability of a generic terminal type K at base NS.

2.3.2 <u>Mean Time Between Demands</u>

The mean time between demands, MTBD, of a given terminal of type K at base NS is developed via the mean time between failures, MTBF, for a given representative of that terminal type. This MTBF is calculated as a sum of the failure rates of the individual LRUs in the terminal:

$$MTBFT(K) = \frac{1}{\sum_{I} QPA(I,K)*MFAC(LE(K))/MOTBMA(I,LE(K))}$$

where QPA(I,K) is the number of LRUs of type I in terminal type K, and with the remaining variables allowing that both predicted and operational mean operating time between maintenance actions are functions of the environment LE(K) of terminal type K (i.e., ground fixed, ground transportable, or airborne) as well as being functions of I, the LRU type. (See the Glossary for the full definitions of the variables involved.)

Mean time between demands differs from mean time between failures in that MTBD is a measure of elapsed calendar time, including times during which the equipment is not operating, if any, whereas MTBF is a measure of actual equipment operating time only. Thus the MTBD of a terminal of type K at base NS is obtained from MTBFT(K) as follows:

$$MTBDT(K,NS) = MTBFT(K)*730/ATOH(K,NS) \quad \text{if } IT(K,NS) > 0$$

$$= 0 \quad \text{if } IT(K,NS) = 0.$$

Effectively, this divides MTBFT(K) by the terminal utilization ratio ATOH(K,NS)/730. Since ATOH(K,NS) is the average total operating hours per month of a terminal of type K at base NS, and there are 730 possible hours per month during which a terminal can operate, ATOH(K,NS)/730 is the fraction of calendar time that the terminal is utilized. (Indeed, certain AFSATCOM terminals of type K in ground fixed environment LE(K)=1 operate continuously, hence the data input for such ground fixed terminals is ATOH(K,NS)=730, for a utilization ratio of 1.0.)

A fully rigorous justification of the above expression for MTBFT(K) requires two further assumptions: First, that the operating times of all LRUs within a terminal accrue at the same rate as the operating time of the terminal itself, and second, that the LRUs within a terminal play a series role, i.e., that failure of any one LRU in the terminal causes failure of the terminal. For a terminal considered as a series system of its component LRUs, we note here an application of a recent result in reliability theory (Reference [9]): For a series *system's mean time between* failures to be a reciprocal of a sum of reciprocal mean times between failures of its component LRUs, it is not necessary to make any further assumptions on LRU up-times and down-times than the modest assumption as presented above for terminal availability.

The above assumptions constitute a simplification of the real system. In actual AFSATCOM usage, each terminal has a "prime mission" objective which can be performed with less than full operational capability, and this "prime mission" capability is protected by a degree of LRU redundancy, i.e., when pursuing such an objective the loss of an LRU need not result in that terminal being shut down. Hence the "prime mission" availability will be higher than that computed by the Availability Routine of the AFSATCOM LCC Model.

2.3.3 Mean Down Time

The mean down time MDT(K,NS) for a particular terminal of type K at base NS is the average time over all LRU repair-replacement outcomes, given a failure of an LRU of type I in terminal type K at base NS, weighted and averaged by the respective probabilities of

failure of the LRU types in the given terminal type. Thus the equation for MDT(K,NS) is

$$
\begin{aligned}
MDT(K,NS) = \sum_{I} & MDTLRU(I,K,NS) \\
& *QPA(I,K)*MTBFT(K)*MFAC(LE(K))/MOTBMA(I,LE(K)) \qquad \text{if } IT(K,NS) > 0 \\
= 0 & \qquad \text{if } IT(K,NS) = 0
\end{aligned}
$$

where MDTLRU(I,K,NS) represents an expression to compute the mean down time for a particular terminal of type K at base NS, given a failure of an LRU of type I in that terminal. This expression is

$$
\begin{aligned}
MDTLRU(I,K,NS) = {} & RMH(I) + MCOTT(K) + TRANB(IBS(I)) \\
& + PCB(I,NS)*TRANS(I,NS).
\end{aligned}
$$

The first three terms of this expression are respectively the average remove and replace time for the LRU, the mean checkout time for the terminal, and the transportation time for on-base delivery of a replacement LRU from the base supply point. Thus these three terms account for time spent at the terminal and on the base exclusive of repair time, given that an LRU of type I has failed. The fourth term, PCB(I,NS)*TRANS(I,NS), is the average remaining time spent over all repair-replacement outcomes given the LRU failure, where TRANS(I,NS) is the mean replacement time given that inventory of LRU type I is depleted at base NS:

$$
\begin{aligned}
TRANS(I,NS) = {} & RTS(I)*RT(I)*BMF \\
& + NRTS(I)*PCD(I)*RT(I)*DMF \\
& + (NRTS(I) + COND(I))*TRAND(LO(NS)).
\end{aligned}
$$

The derivation of the expression for MDTLRU(I,K,NS), including a detailed derivation of TRANS(I,NS), is presented in Appendix C. Definitions of all FORTRAN variables will be found in the Glossary, along with identification of the responsible authority or source of numerical data for input variables.

The above expressions for MDTLRU(I,K,NS) and TRANS(I,NS) employ two probabilities evaluated by the Expected Backorder Sparing Routine (EBOS) as output variable PC (refer to Exhibit 4): For LRU type I, PCB(I,NS) is the probability that inventory is depleted at base NS, and PCD(I) is the probability that inventory is depleted at the depot. (See Glossary for more complete definitions.)

The remaining factors of the MDT(K,NS) equation above,

QPA(I,K)*MTBFT(K)*MFAC(LE(K))/MOTBMA(I,LE(K)),

constitute the probability of failure of LRU type I in terminal type K. To see this, rewrite the above as

[QPA(I,K)*MFAC(LE(K))/MOTBMA(I,LE(K))] / [1/MTBFT(K)]

which is merely a ratio of LRU type I failure rate (per operating hour in terminal type K) to the failure rate of terminal type K (per operating hour). Recall our assumption that the operating times of all LRUs within a terminal accrue at the same rate as the operating time of the terminal itself. Finally, the defining expression for MTBFT(K), presented at the beginning of this subsection, justifies that

$$\sum_{I} [QPA(I,K)*MFAC(LE(K))/MOTBMA(I,LE(K))] \;/\; [1/MTBFT(K)] = 1$$

as should be the case for probabilities on I with a given K.

SECTION 3

THE AFSATCOM LCC MODEL WITH "CENTRALIZED" MAINTENANCE POSTURE

The AFSATCOM LCC Model is capable of operation according to either of two maintenance postures: "non-centralized" maintenance or "centralized" maintenance. Both maintenance postures, and associated terminology, were presented in Sections 1 and 2. The remainder of Section 2 documented the AFSATCOM LCC Model under the "non-centralized" maintenance posture. In this section only the changes which convert the model from "non-centralized" to "centralized" maintenance posture will be discussed.

3.0.1 Subroutine CONSO

Subroutine CONSO is the vehicle by which the "centralized" maintenance posture is implemented. Maintenance posture is governed by the user's control variable CON. Setting CON=0 causes the model to run in "non-centralized" maintenance posture. Setting CON=1 causes Subroutine CONSO to be called, and the model to run in "centralized" maintenance posture. For the remainder of the discussion, it is assumed that the user has set CON=1. Subroutine CONSO performs the following sequence of events: First, a FORTRAN logical variable is set, and a configuration of the bases into stand-alone bases (i.e., bases not assigned to any group), groupings, and "centralized intermediate maintenance facilities" or CIMFs, as determined by the user, is received as input. The FORTRAN variable through which the user inputs a desired configuration is the vector CONSOL(NS) for bases sequenced as NS; this vector is discussed below and in the Glossary. The subroutine provides as output a pointer ICS(NS) for base indices NS to identify the groupings, and an indicator (zero or one) function CIMF(NS) to identify those bases at which repair facilities are located.

To simplify the presentation, the logical variable and the pointer will not be discussed in detail; it will be understood in all of the following discussions that "centralized" maintenance posture prevails, and that the stand-alone bases, the groupings, and the CIMFs are identified as a function of their indices NS.

Many base-specific variables are read as input into data files, or computed internally and stored in data files, via an indexing procedure which is independent of whether "non-centralized" or "centralized" maintenance posture is employed. As a result, certain

variables which appear in this document as functions of index NS actually appear in the FORTRAN program as functions of the pointer ICS(NS), e.g., input variables ATOH(K,NS) and PS(LO(NS)), and the internally computed FAIL(I,K,NS) are actually programmed as ATOH(K,NS1), PS(LO(NS1)), and FAIL(I,K,NS1) where NS1=NS for "non-centralized" maintenance posture, NS1=ICS(NS) for "centralized" maintenance posture. Identifying NS1 with NS for the purpose of simplifying the presentation would technically represent the fortuitous case whereby the data files are sequenced by base exactly as the stand-alone and grouping configuration vector CONSOL(NS) sequences the bases.

A sample input configuration is shown in Exhibit 5, along with the corresponding input vector CONSOL(NS) which produces it, and the Subroutine CONSO outputs ICS(NS) and CIMF(NS). Note that the bases are coded as two-character alphanumeric symbols delimited by a double-zero symbol. The first such string identifies the stand-alone bases. Each successive string identifies a grouping of bases, the last of which is the CIMF for that grouping. To emphasize that the choice of indices NS is independent of the configuration, a randomized sequence is shown.

The indicator function CIMF(NS) is defined and used only with the centralized maintenance posture. Interpretation is as follows:

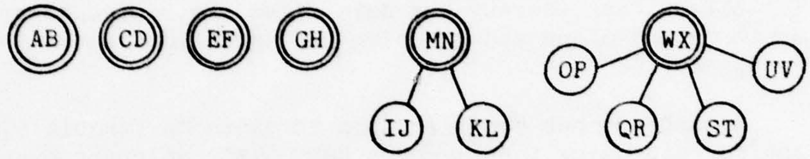
CIMF(NS) = 1 if base NS is either a stand-alone base or the CIMF for a group of bases

= 0 if base NS is part of a group of bases but not the CIMF for that group.

By the above definition of CIMF(NS), a stand-alone base is technically a CIMF base, servicing only itself. From the standpoint of repair activity, CIMF(NS)=1 denotes repair activity at base NS, whereas CIMF(NS)=0 signifies that base NS sends equipment to a CIMF elsewhere.

Base	EF	KL	UV	WX	QR	AB	ST	OP	MN	IJ	CD	GH
NS1	1	2	3	4	5	6	7	8	9	10	11	12

(a) The Bases as Sequenced by Indices NS1.



(b) The Desired Configuration for Centralized Maintenance Posture, Double-Circles Denoting Bases with Repair Facilities.

```
CONSOL(NS) = 'AB','CD','EF','GH','00','IJ','KL',
             'MN','00','OP','QR','ST','UV','WX','00'
```

(c) The Corresponding Input Vector CONSOL(NS) to Subroutine CONSO, to Achieve the Desired Configuration.

Base	AB	CD	EF	GH	IJ	KL	MN	OP	QR	ST	UV	WX
NS	1	2	3	4	5	6	7	8	9	10	11	12
ICS(NS)	6	11	1	12	10	2	9	8	5	7	3	4
CIMF(NS)	1	1	1	1	0	0	1	0	0	0	0	1

(d) The Bases as Sequenced by Input Vector CONSOL(NS), with Subroutine CONSO Outputs ICS(NS) and CIMF(NS).

Exhibit 5. A Sample Configuration of Twelve Bases for Centralized Maintenance Posture, with the Corresponding Subroutine CONSO Inputs and Outputs.

3.0.2 Sets of Bases (Notation)

To facilitate the documentation of the AFSATCOM LCC Model under centralized maintenance posture, the following sets are defined:

$$Y = \{NS: \ CIMF(NS) = 1\},$$

i.e., Y is the set of bases NS which have repair facilities; for each such base NS which serves as a CIMF to bases ns′ without repair facilities,

$$Z(NS) = \{ns': \ CIMF(ns') = 0 \text{ and base } ns' \text{ is serviced by CIMF base } NS\},$$

i.e., Z(NS) is the set of bases serviced by a given CIMF base NS (excluding base NS itself).

Summation notation such as

$$\sum_{NS \in Y} f(NS), \qquad \sum_{ns' \in Z(NS)} f(ns')$$

will imply the following operations: The summation on $ns' \in Z(NS)$ is taken over all bases ns′ which are serviced by a given CIMF base NS (excluding base NS itself), with the proviso that this summation is zero if base NS is a stand-alone base, i.e., a CIMF servicing only itself; the summation on $NS \in Y$ is taken over all bases NS which have repair facilities.

3.0.3 Composite Failure Rate of Shipments to CIMF

The following summation appears frequently in the sequel and will be designated as FAILC(I,K,NS):

$$FAILC(I,K,NS) = \sum_{ns' \in Z(NS)} FAIL(I,K,ns'),$$

with the proviso that this summation is zero if base NS is a stand-alone base, i.e., a CIMF servicing only itself. Here FAIL(I,K,ns′) is as in Section 2.1 for non-centralized maintenance posture, namely, the expected number of removals per month of LRU type I in terminal type K at base ns′. Thus FAILC(I,K,NS) denotes the composite expected number of removals per month of LRU type I in terminal type K among shipments from bases ns′ without repair facilities, to a given CIMF base NS.

3.1 The LCC Cost Element Equations

Differences between documentation for "non-centralized" maintenance posture and documentation for "centralized" maintenance posture occur in only seven of the eleven cost elements, namely in Cost Elements 2, 4, 5, and 7 through 10. These differences are listed below.

It is important to note that by programming the AFSATCOM LCC Model to perform summations over the sets of bases $\{NS \in Y\}$ and $\{ns' \in Z(NS)\}$ instead of over all bases NS, model runs may be switched from one maintenance posture to the other without requiring revision of the supporting data files. For example, the file of MMTB(NS), minimum number of men planned for initial training to support AFSATCOM at base NS, is permitted to contain nonzero entries at bases NS which under centralized maintenance posture will not have repair facilities. In centralized maintenance posture, such entries are not used by the model, since the bases involved lie outside the set over which the calculations are performed. (See, in support of this example, Appendix A, Exhibit 7, Table 14: "Required Men to Be Trained." Note in particular that for certain bases NS, the input MMTB(NS) is nonzero but the computed output NMT(NS) is zero.)

3.1.1 Cost Element 2 (Spares Acquisition)

The equation for SC(2) remains formally as in Section 2.1, but the input SB(I,NS) is calculated by the Sparing Routine as discussed in Section 3.2 below. (In particular, SB(I,NS) is Sparing Routine output variable QS when Sparing Routine input variable AS is as discussed in Subsections 3.2.1.1 and 3.2.1.2, "Load Factor for Base Inventory, Base Not a CIMF" and "Load Factor for Base Inventory, Base a CIMF.")

3.1.2 Cost Element 4 ("Off-Equipment" Repairs)

For centralized maintenance posture, the equation for this cost element becomes

$$SC(4) = 12*PIUP*\{ \sum_{NS} \sum_{K} \sum_{I} FAIL(I,K,NS)*HPF(I)$$

$$+ \sum_{NS\in Y} \sum_{K} \sum_{I} [FAIL(I,K,NS)*RTF(I,NS)$$

$$+ FAILC(I,K,NS)*RTFC(I,NS)] \}$$

in which the expected number of removals per month FAIL(I,K,NS) is as in Section 2.1 for non-centralized maintenance posture, and FAILC(I,K,NS) is the composite expected number of removals to CIMFs as discussed above. The expected costs per removal HPF(I) and RTF(I,NS) are defined as for non-centralized maintenance posture but using a new factor KC in place of KB,

$$HPF(I) = BLR*RTS(I)*RT(I)*BMF*KC$$
$$+ DLR*NRTS(I)*RT(I)*DMF*KD,$$

and

$$RTF(I,NS) = PS(LO(NS))*PWR(LO(NS))*KC$$
$$*(2*NRTS(I) + COND(I))*WT(I).$$

Associated with FAILC(I,K,NS) is a new expected cost per removal,

$$RTFC(I,NS) = PS(LO(NS))*PWR(LO(NS))*KC*2*WT(I).$$

The summation involving HPF(I) includes all bases NS, whereas the summation involving RTF(I,NS) and RTFC(I,NS) concerns only the bases NS at which maintenance facilities exist. (Recall from above that FAILC(I,K,NS) is itself a summation, for a given CIMF base NS, involving all bases ns′ which send equipment to the maintenance facility at base NS, with the proviso that FAILC(I,K,NS) is zero if base NS is a stand-alone base, i.e., a CIMF servicing only itself.)

As is the structure for non-centralized maintenance posture, the factor

```
(2*NRTS(I) + COND(I))*WT(I)
```

in RTF(I,NS) tallies twice the net weight WT(I) of LRU type I if on a round trip to depot for repair and return, once the net weight if on a one-way trip from the depot to replace a condemned LRU. In RTFC(I,NS) the comparable factor is merely 2*WT(I); in centralized maintenance posture <u>all</u> failed LRUs originating at a base which is not a CIMF must be sent to the appropriate CIMF before the appropriate repair-level decision (base repair, depot repair, or condemn) can be implemented, hence a round-trip tally is put to every such LRU.

As for non-centralized maintenance posture, the factor 12*PIUP is replaced by the continuously discounted sum DFC(A,B,R) with A=0, B=12*PIUP, if a monthly interest rate $R \neq 0$ is provided.

In the actual FORTRAN program, SITELCC, for the AFSATCOM LCC Model, the three-dimensional entities FAIL(I,K,NS) and FAILC(I,K,NS) are computed as scalars and summed at the innermost level of a three-level nest of DO-loops. As discussed in Section 2.1, Cost Element 4, for non-centralized maintenance posture, FAIL(I,K,NS) is summed into the two-dimensional arrays XF(I,K) and XFB(I,NS). In addition, under centralized maintenance posture, Cost Element 4 employs a third array:

$$\mathrm{XFBN(I,NS)} = \sum_{K} \mathrm{FAILC(I,K,NS)}.$$

The physical interpretation of XFBN(I,NS) is the composite expected number of removals (failures) of LRU type I among shipments from bases without repair facilities to a given CIMF base NS.

3.1.3 <u>Cost Element 5 (Replacement LRUs and SRUs)</u>

This cost element undergoes two differences when employing centralized maintenance posture instead of non-centralized maintenance posture. The first is a formal change in the equation for SC(5), using KC in place of KB:

$$SC(5) = 12*PIUP \sum_{NS} \sum_{K} \sum_{I} FAIL(I,K,NS)*[COND(I)*UC(I) + (RTS(I)*KC + NRTS(I)*KD)*ASEC(I)].$$

The second difference is in the computed value of ASEC(I) via inputs RTS(J), NRTS(J), COND(J), and CPFB(J), CPFD(J), CPFS(J), where J identifies SRU type; these six inputs are outputs of an ORLA Routine [3] run at the SRU level and may vary with maintenance posture. In particular, the latter three inputs, CPFB(J), CPFD(J), and CPFS(J), are computed by the SITEORLA Routine which itself has provision for both non-centralized and centralized maintenance posture.

3.1.4 <u>Cost Element 7 (Support Equipment)</u>

The equation for SC(7) remains formally as in Section 2.1; the sole difference for centralized maintenance posture occurs in the formula for ERHB(I,K,NS), the expected number of repair hours per month that LRUs of type I operating in terminals of type K will require at a repair shop at base NS:

$$ERHB(I,K,NS) = [FAIL(I,K,NS) + FAILC(I,K,NS)] *RTS(I)*RT(I)*BMF*KC \quad \text{if} \quad CIMF(NS) = 1$$

$$ERHB(I,K,NS) = 0 \quad \text{if} \quad CIMF(NS) = 0.$$

Thus no SE is purchased for a base unless a maintenance facility exists there, and in the computation of the number of SE items to be purchased for a CIMF base NS, the bases ns′ which send equipment to that maintenance facility are included.

<u>Note</u>: For purposes of comparison between use of base repair personnel and use of organizational-level personnel for AFSATCOM, by

LRU type and base, the following computation is performed and summed over terminal types K for bases NS without repair shops:

$$\text{ERMH(I,K,NS)} = \text{FAIL(I,K,NS)*RMH(I)*BMF} \qquad \text{if} \quad \text{CIMF(NS)} = 0,$$

where ERMH(I,K,NS) here denotes the expected number of hours of organizational-level labor, per month, required to remove and replace LRUs of type I operating in terminals of type K at base NS. The AFSATCOM LCC Model output reports present these data in place of the zero-valued ERHB(I,K,NS) when base NS does not have a repair shop. (See Appendix A, discussion of Table 11.)

3.1.5 Cost Element 8 (Initial Training)

The equation for SC(8) remains as in Section 2.1; the sole differences for centralized maintenance posture occur in the formula for ERPSB(NS), the expected repair time required in man-hours/month at base NS, and in the computation of NMT(NS), the number of men trained for base level maintenance work at base NS:

$$\text{ERPSB(NS)} = \sum_K \sum_I [\text{FAIL(I,K,NS)} + \text{FAILC(I,K,NS)}] \text{*(RTS(I)*RT(I)*BMF*KC + RMH(I))} \qquad \text{if CIMF(NS)} = 1$$

$$\text{ERPSB(NS)} = 0 \qquad \text{if CIMF(NS)} = 0,$$

and

$$\text{NMT(NS)} = \text{Max } \{ \text{MMTB(NS)}, [\text{NPERB(NS)}]^{+} \} \qquad \text{if CIMF(NS)} = 1$$

$$= 0 \qquad \text{if CIMF(NS)} = 0$$

where $[...]^{+}$ denotes rounding up to the next higher integer.

Thus in the computations of ERPSB(NS), NPERB(NS), NMT(NS), and NMTB, the bases ns′ which send equipment to a given CIMF base NS are included with that CIMF. (Recall from above the defining summation for FAILC(I,K,NS).)

3.1.6 Cost Element 9 (Recurring Training)

There is formally no change in the equation for SC(9) as given in Section 2.1; however, the value used for NMT(NS) is that computed for Cost Element 8, above, for centralized maintenance posture.

3.1.7 Cost Element 10 (New Item Inventory Management)

The equation for SC(10) remains formally as in Section 2.1; the sole difference for centralized maintenance posture involves use of the function CIMF(NS) in the computation of NCIS(I):

$$NCIS(I) = \sum_{NS \in Y} U\left(\sum_{K} QPA(I,K)*IT(K,NS)*RTS(I)\right)$$

where Y is the set of bases NS for which CIMF(NS)=1.

3.2 The Sparing Routine

The Expected Backorder Sparing Routine, EBOS, is independent of whether sparing is computed for base or depot inventories, and independent of whether maintenance posture is "non-centralized" or "centralized." These concerns affect the use of the Sparing Routine, but do not affect the Sparing Routine itself.

3.2.1 Inputs

The procedure by which the load factor, AS, is evaluated is a function of maintenance posture. Subsection 2.2.2.1, "Load Factor for Base Inventory," is to be replaced by Subsections 3.2.1.1 and 3.2.1.2 presented below, for centralized maintenance posture. Subsection 2.2.2.2, "Load Factor for Depot Inventory," is the same for either maintenance posture.

The upper limit for expected backorders, AX, is evaluated directly from input data; hence the discussion of Section 2.2 is applicable here as well.

Calculation of the remaining input to the Sparing Routine, expediting factor EXF, is governed by the user′s control variable

NEXF. Modifications to this procedure, under centralized maintenance posture, are presented in Subsection 3.2.1.3, "Expediting Factor," below.

3.2.1.1 Load Factor for Base Inventory, Base Not a CIMF: For each given LRU type I at a given base NS for which CIMF(NS)=0, base inventory is obtained by calling the Sparing Routine with load factor AS computed in advance as

```
AB(I,NS) = XFB(I,NS)
           *[RTS(I)*CRCT*KC + (NRTS(I)*KD + COND(I))*OST(LO(NS))].
```

Note, upon comparison with the equivalent expression in Section 2.2, that the variables BRCT and KB have been replaced by CRCT and KC respectively, with the remainder of the expression unchanged. (All FORTRAN variables which appear above are defined in the Glossary.)

3.2.1.2 Load Factor for Base Inventory, Base a CIMF: For each given LRU type I at a given base NS for which CIMF(NS)=1, base inventory is obtained by calling the Sparing Routine with load factor AS computed in advance as

```
AB(I,NS)  = XFB(I,NS)
            *[RTS(I)*BRCT*KB + (NRTS(I)*KD + COND(I))*OST(LO(NS))]

            + XFBN(I,NS)
              *[RTS(I)*CRCT*KC + (NRTS(I)*KD + COND(I))*OST(LO(NS))].
```

Note that this load factor is the sum of an expression which considers the CIMF's own failures, with base repair cycle time BRCT (multiplied by KB) if RTS(I)≠0, plus an expression which considers the failures from all bases serviced by the CIMF, using CRCT and KC in place of BRCT and KB. The use of CRCT*KC in establishing base inventory for a base which is not a CIMF is to insure a supply during the time required to receive replenishment from the CIMF. The use of CRCT*KC in establishing inventory at the CIMF is to allow for the CIMF's own pipeline time: one-way shipping time to receive the failed LRU, plus a CIMF handling and repair time which is considered negligible with respect to CRCT.

3.2.1.3 Expediting Factor: Under centralized maintenance posture, with user's control variable NEXF=0, the calculation of expediting factor EXF(I,NS) in the calling procedure for Subroutine EBOS (for computation of PCB(I,NS)) differs from that of non-centralized maintenance posture as follows:

If base NS is not a CIMF, i.e., CIMF(NS)=0, then in the numerator of the formula for EXF(I,NS) the expression in brackets is replaced by

$$[RTS(I)*CRCT + (1-RTS(I))*OST(LO(NS))],$$

and to the denominator is added

$$RTS(I)*TRANC$$

to account for the additional transportation time for shipment from the CIMF, via an expedited priority, of the replacement LRU repaired at the CIMF.

If base NS is a CIMF, i.e., CIMF(NS)=1, then in the numerator of the formula for EXF(I,NS) the expression in brackets is replaced by

$$RTS(I)* \left[\frac{XFB(I,NS)*BRCT + XFBN(I,NS)*CRCT}{XFB(I,NS) + XFBN(I,NS)} \right] + (1-RTS(I))*OST(LO(NS))$$

in which BRCT and CRCT are weighted appropriately according to the original source (CIMF or non-CIMF) of the LRU failure. For a CIMF base NS, the denominator of the formula for EXF(I,NS) is identical to that for non-centralized maintenance posture, since in this case the base-level repair is made at the same base where the LRU is installed.

Note that in the above, the numerator expressions involve precisely the ratios AB(I,NS)/XFB(I,NS) from Subsection 3.2.1.1, "Load Factor for Base Inventory, Base Not a CIMF," or AB(I,NS)/[XFB(I,NS) + XFBN(I,NS)] from Subsection 3.2.1.2, "Load Factor for Base Inventory, Base a CIMF," but without the multipliers

KB, KC, or KD. These relations are analogous to that noted in Section 2.2 for non-centralized maintenance posture.

3.2.2 Outputs

The Sparing Routine itself is not affected by maintenance posture; hence the discussions of Section 2.2 for the output variables QS, EBO, and PC are applicable here as well.

The interpretation of QS, quantity of spares to be acquired, is according to the procedure by which the load factor is computed as input to the Sparing Routine. (See, in particular, Subsection 3.2.1.2, "Load Factor for Base Inventory, Base a CIMF," above.)

The interpretation of PC, probability of backordering, is controlled by the Sparing Routine calling procedure. Thus PC may pass to the Availability Routine (Section 3.3, below) as the probability of LRU type I inventory depleted at a base NS which is not a CIMF, at a base NS which is a CIMF (according to whether CIMF(NS)=0 or 1), or at the depot. For interpretation of PC at a CIMF base, from the standpoint of a non-CIMF base serviced by that base, see discussion of PCC(I,NS), below.

3.3 The Availability Routine

In the Availability Routine, the expression for mean down time must be modified in order to convert from non-centralized maintenance posture to centralized maintenance posture; the remainder of the Availability Routine is unaffected by maintenance posture.

3.3.1 Mean Down Time

The mean down time MDT(K,NS) for a particular terminal of type K at base NS, as a summation on I of an expression involving MDTLRU(I,K,NS), remains formally as presented in Section 2.3 above. Similarly, there is no change in the formal expression for MDTLRU(I,K,NS), involving TRANS(I,NS). However, the formula for TRANS(I,NS) is different under centralized maintenance posture, since the pipeline description which contributes to this expression must make allowances for CIMF inventories and CIMF repairs when applicable:

```
TRANS(I,NS) = RTS(I)*CIMF(NS)*RT(I)*BMF
                    + RTS(I)*(1-CIMF(NS))*[TRANC+PCC(I,NS)*RT(I)*BMF]
                         + NRTS(I)*PCD(I)*RT(I)*DMF
                         + (NRTS(I) + COND(I))*TRAND(LO(NS)).
```

See Appendix C for a detailed derivation of the above formula.

A new probability PCC(I,NS) appears in the expression for TRANS(I,NS) when using centralized maintenance posture. For a base NS such that CIMF(NS)=0, PCC(I,NS) is the probability that inventory of LRU type I is depleted at the CIMF which services the non-CIMF base NS. (See Glossary for a more complete definition.) Actual computation of PCC(I,NS) involves both the Sparing Routine and an output of Subroutine CONSO:

```
PCC(I,NS) = PCB(I,NS´)
```

where NS´ is the index of the base which serves as CIMF for base NS. (See discussion of Subroutine CONSO and Exhibit 5.) PCB(I,NS´) is evaluated by the Sparing Routine for LRU type I and base NS´ exactly as discussed previously for non-centralized maintenance posture. (See Exhibit 4.)

APPENDIX A

OUTPUT REPORTS OF THE AFSATCOM LCC MODEL

The output reports from the AFSATCOM LCC Model are classified into two groups. The first group is a set of tables that display values of input data items, and, in a few cases, results of preliminary* calculations. This group of ten reports is designated the "Input Section". The second group of nine reports, the "Output Section", includes tables which display the results of cost, support requirements, and performance calculations.

Life cycle costs computed by the model are presented in the output reports as total system LCC (defined as the sum of the eleven cost elements of the LCC Routine) and by cost element. Where possible by the equation structure of the model, certain cost elements are further broken down by LRU type and/or by terminal type. Results of non-cost calculations are printed out at the following detailed levels of aggregation: by LRU type, terminal type, SE (support equipment) item, and/or site (base or depot).

Exhibit 6, the AFSATCOM LCC Model Output Table Directory, presents an overview of the model's inputs and outputs. Each table is listed and its contents categorized by both type of data and level of aggregation. Output tables have been classified as displaying either input parameters (I), cost calculations (C), or non-cost calculations (N). The levels of aggregation at which the data are collected or presented are LRU, terminal, environment, site, SE item, and cost element.

The computer printouts included in this Appendix as Exhibit 7 are a set of actual output reports from a sample run of the AFSATCOM LCC Model. The data on which the run is based are not comprehensive; that is, not all LRU types, terminal types, bases, and SE items in the AFSATCOM system are represented in this model run. The model has capacity for

- up to 135 different LRU types;
- up to 30 different terminal types;
- up to 95 sites (94 bases, one depot); and
- up to 200 different SE items.

---

*An example of a "preliminary calculation" is an aggregation of detailed input data to a higher level which is subsequently used in a system cost or non-cost calculation.

However, the reader's understanding of the model can be enhanced by referencing these output reports in conjunction with the text of this document. At the same time, it should be noted that several of the model's quantitative calculations and analytical capabilities are not visible from these output reports (not all calculations are printed) but are used in generating the information currently provided. Examples include the calculation of probabilities of backordering (PCB(I,NS), PCD(I)) and expected backorder quantities (EBO).

Each report of the AFSATCOM LCC Model which appears in Exhibit 7 is described in the remainder of Appendix A. Report descriptions include explanations of the parameters and variables displayed in each table as well as other information which relates the reports to each other and to appropriate sections of the text and the Glossary.

INPUT SECTION

Miscellaneous Parameter Values

The first report of the Input Section, "Miscellaneous Parameter Values," lists the values of several parameters for the current model run. Many of these parameters are included in non-cost calculations and cost element equations; others relate only to the mechanics of the computer program. The parameter values are stored in two FORTRAN Namelists, $SYS and $LCC.

Of particular interest in the sample run employed for Exhibit 7 is the fact that CON=1, implying the centralized maintenance posture. The vector CONSOL, which also appears in $SYS, reveals that (refer to discussion of Subroutine CONSO in the text) the bases A1, A2, and A3 stand alone, whereas bases B1, B2, B3 and C1 are grouped with C1 the CIMF; also, B4, B5, B6, and C2 are grouped with C2 the CIMF, and B7, B8, B9, and C3 are grouped with C3 the CIMF.

Table 1: Quantity of Terminal Type by Site

The next report is a matrix of terminals by site. Each matrix column in Table 1 indicates the quantity of a particular AFSATCOM terminal type at each base. Each row, conversely, represents the terminal mix at a particular base. The first two characters under the column entitled "LO" are a base location index indicating whether the site is CONUS or overseas; the third character indicates the type of maintenance bench set (if any is used at that base) for that site. The matrix of Table 1, with quantity of one each implied for terminal types which appear in the "UNIQUE" column, corresponds to the matrix IT(K,NS) in the text.

Table 2: Predicted Average Terminal Operating Hours/Month

The predicted average terminal operating hours/month are shown by terminal type and site in the next report, Table 2. The placement of entries in Table 2 coincides with the location of matrix entries in Table 1. If a terminal type is used at a given site, the average number of operating hours per month for that type of terminal will be displayed. The entry "730" represents 100% terminal utilization, this being the average number of hours per month. The matrix of Table 2 corresponds to the matrix ATOH(K,NS) in the text.

Table 3: LRU Reference Table

The following data are shown in Table 3 for each LRU:

a. LRU index number
b. LRU name
c. Work Unit Code (WUC)
d. Part Number
e. Information concerning Maintenance Bench Sets (MBS)
f. Choice of Repair Levels
g. LRU prices
h. LRU quantity

Item a defines an index number that is used throughout the LCC Model run to refer a particular LRU by type. Items b, c, and d require no additional explanation. The value of item e, if non-zero for a particular LRU, indicates the set of MBS types NHM with which this LRU can be repaired. Item f, choice of Repair Level, is documented in a note at the end of Table 3. One of these three options can be designated by the user by modifying the input parameter "NRL" in the Namelist $LCC of the "Miscellaneous Parameter Values" table. LRU prices, Item g, permits the inclusion of indices for varying the LRU base cost to incorporate learning curve discounts, economic escalation, and mark-ups reflecting general administrative expenses and contractor fees. The final data item, LRU quantity, displays the results of a preliminary calculation. Under the heading "QTY" is the total quantity of LRUs of this type "purchased" to comprise the terminals for this run, denoted as QLRU1(I) in the text.

Table 4: LRU Quantities by Terminal Type

Table 4 shows the LRU configuration that comprises each terminal type associated with the AFSATCOM system. This matrix contains configuration data for all terminal types, regardless of whether a specific terminal type is included in a particular run of the AFSATCOM LCC Model. Therefore, Table 4 could display data for terminal types that are not

shown in Tables 1 and 2. The matrix of Table 4 corresponds to the matrix QPA(I,K) in the text.

Also shown, in the row designated "LE" immediately under the terminal types, is the corresponding terminal environment. This index is denoted LE(K) in the text and is defined in the description of Table 6, below, and in the Glossary.

Table 5: LRU Operation and Support Parameters

Input values for several LRU-dependent parameters are shown in Table 5. These parameters include ASEC, TW, UC, WT, RT, RMH, PA, TDLP, RTS, NRTS, and COND. Each parameter is defined in the Glossary; in addition, a brief description appears in a note at the foot of the table.

Table 6: Predicted LRU MTBF by Environment

Table 6 displays the predicted mean time between failures for each LRU type as a function of its anticipated operating environment. The three terminal operating environments are 1) ground-fixed terminals in 30°C conditions, 2) ground-transportable terminals in 30°C surroundings, and 3) airborne terminals in a 40°C environment. Matrix entries are expressed in number of hours. These entries correspond to MOTBMA(I,LE) for LRU type I in environment LE, in the text.

Table 7: Reliability K Factor by Environment

Values for MFAC(LE) are shown in Table 7. Each MFAC value corresponds to one of the three terminal operating environments discussed in the description of Table 6. The MTBF used in the AFSATCOM LCC Model is the value given in Table 6 divided by the appropriate value of MFAC.

Table 8: SE Cost by SERD Number
Total SE Hardware Acquisition Cost

The first part of Table 8 displays input data for each item of peculiar support equipment (SE). The first two columns of the printout, SERD and DESCRIPTION, display the SE Item Number, name and the manufacturer's part number for each SE Item.

The four cost options represent the breakpoint SE costs for various lot size purchases. If the breakpoint costs are used, Cost 1 is selected by the model if the SE lot size is less than or equal to 3; Cost 2 is chosen if the lot size is greater than 3 but less than or equal to 27; Cost 3 is used if the lot size ranges from 28-49; and Cost 4 is selected if the lot size exceeds 49. The values of the breakpoints can be specified by the user. They are shown in Namelist $SYS of the "Miscellaneous Parameter Values" table as N1, N2, and N3.

The parameter IFL allows the user to control the application of these breakpoint costs for particular SE items. If the value of IFL is 0, the procedure described above is employed. If IFL = 1, the procedure is not employed and Cost 1 is used. SE Items for which $1 < IFL < 100$ are actually LRUs, so the SE price is set equal to the price of the LRU numbered IFL.

The second part of Table 8 exhibits the acquisition cost for all support equipment "purchased" in this LCC model run. The figure is subdivided into three components - Peculiar SE, Common SE, and those SE which are actually LRUs.

Table 9: LRU-SE Usage Matrix

The data shown in Table 9 display both the types and quantities of peculiar support equipment that are needed to repair each LRU. The tabular schematic of Table 9 is a simplified version of the input matrix A(I,L); it was designed to minimize the storage requirements of this large matrix by recording only the non-zero elements.

The leftmost number in Table 9 is the LRU index number. The next one or two digits represent the total number of SE items that are needed to repair this LRU. The top row of numerals are the item numbers of the SE used to repair that LRU; the figure directly beneath each of these SE item numbers represents the quantity of that SE item which is used to repair the LRU.

OUTPUT SECTION

Table 10: Number of Required Spares by Site by LRU
Expected Failures per Month

Table 10, the first report in the Output Section, shows the results of two sets of calculations. In both cases, an array of data computed at the base level is printed out for each LRU.

The table on the left-hand side of the report, "No. of Required Spares by Site by LRU," exhibits the total number of base level spare LRUs required to fulfill a minimum average AF inventory level specification (see AX and EBO in Glossary), as determined by the Sparing Routine documented in Section 1.2. A breakdown of the LRU spares total by base (SB(I,NS) in the text) appears in ten-column tabular format* below the sum for each LRU type. The NS site index corresponds to those defined in Table 1.

---

*Here and in several other places throughout Tables 10, 11 and 13, one-dimensional (vector) data will be presented in a ten-column tabular format to be read left to right and top down. This format facilitates locating any entry given its index; the upper left entry is always blank, followed by entries for indices 1 through 9. Subsequent rows contain the entries for indices 10 through 19, 20 through 29, etc.

After sparing quantities for the last LRU have been printed, a table containing similar data for the depot (SD(I) in the text) appears. These tabular entries represent numbers of spares by LRU type.

The right-hand side of Table 10 displays the total number of expected failures per month, by LRU, at each base (XFB(I,NS) in the text).

Table 11: Expected Repair Hours per Month for All LRUs by Site
No. of LRUs of Type I by Site

Table 11 also displays two types of calculations. In this case, two varieties of data are printed out for each LRU (in ten-column tabular format) by base. The left-hand table contains data signifying the expected number of repair hours per month for each LRU type at each base, i.e., $\sum_K$ ERHB(I,K,NS). For bases without repair shops (identifiable via the vector CONSOL in the "Miscellaneous Parameter Values" table), the expected number of repair hours is necessarily zero. For such bases, the presentation by LRU type is instead the expected number of hours of organizational-level labor required per month for remove-and-replace operations, i.e., $\sum_K$ ERMH(I,K,NS). Hours for LRU repair at the depot (representing $\sum_K$ ERHD(I,K)) appear after the figures for the last base.

The right-hand side of Table 11 is a breakdown by base of the "QTY" figures in Table 3, denoted in the text as QLB1(I,NS) for LRU type I at base NS. The number of LRUs of each type is printed in tabular format for every base. The last table in this sequence, located next to the Depot LRU Repair Hours array, exhibits the number of bases where each LRU type is used. This table is derived by accumulating a unit entry for every instance in which any number of LRUs of a given type is used at any base. (Refer to NIS(I) in the Glossary and in the discussion of Cost Element 10.)

The information in Table 11 is often useful in locating input data errors.

Table 12: Availability, Mean Down Time, and MTBD for Terminal K by Site

Values for three variables are shown in Table 12 by terminal type and base. These variables are the availability, mean down time, and mean time between demands for terminal type K at base NS, denoted respectively in the text as AV(K,NS), MDT(K,NS), and MTBDT(K,NS). The three values comprising each matrix "entry" are expressed as a probability for availability and in number of hours for mean down time and mean time between demands.

Data by base are shown horizontally; terminal data can be read vertically below each terminal designation. The last column of Table 12 is used in the same manner as the "UNIQUE" column of Table 1.

(Note that the last column of Table 12 contains non-zero entries for the same terminal types and bases as in the corresponding column of Table 1.)

Table 13: Required SE Items to Be Purchased
Expected SE Utilization

Table 13 presents the results of two types of calculations. The left-hand side of the printout displays, in ten-column tabular format, the quantities of each type of peculiar support equipment (SE) that the AF must purchase for a particular site to repair LRU failures in this LCC model run. The first tabular array in this category exhibits values of the variable NAPD(L); the next several such arrays display values of NAPB(L,NS). If no SE is to be purchased for a particular base, a message to that effect is printed. The last array, entitled "Total Number of SE Items Purchased," shows the aggregation of these SE item quantities over all bases and the depot. (Elements of this final tabular array are described in the text as NAPH(L).)

The expected utilization times for each of these SE items, expressed in hours/month, are shown in a sequence of ten-column tabular arrays on the right-hand side of the printout. The SE utilization data for each base are presented opposite the corresponding Required SE Items to be Purchased. Therefore, expected utilization times for the depot (ERHAD(L)) appear first, followed by figures for each base (ERHAB(L,NS)).

(Recall from the discussion following the "Miscellaneous Parameter Values" table, above, that the sample model run employed for Exhibit 7 uses centralized maintenance posture. It is of interest to note that in Table 13 the statements "NO SE FOR THIS SITE" are printed out precisely for those bases which ship their failed equipment to a CIMF elsewhere.)

Table 14: Required Men to Be Trained

Selected input data and training calculations appear in Table 14. The table heading states two assumptions of the calculations, i.e., values of BAA and DAA are as shown here for this LCC model run. (BAA and DAA are also included in the "Miscellaneous Parameter Values" table.)

Input and computed values are presented for the following four parameters and variables for each base NS and for the depot: Minimum number of men to be trained (denoted MMTB(NS) for base NS, MMTD for the depot), AF training turnover rate (denoted TRB(NS), TRD), number of men trained (the output computed by the model, denoted NMT(NS) for

base NS, NMTD for the depot), and the fraction utilization of a one-man shop (denoted NPERB(NS) for base NS, NPERD for the depot).

(Note that for bases NS which send their repair work to a CIMF elsehwere, the input MMTB(NS) may be non-zero, but the model outputs NMT(NS) and NPERB(NS) are zero.)

Table 15: Systems Cost

Table 15 is the first of four tables which display results of the system cost element calculations. Table 15 exhibits the total LCC for this run, broken down into acquisition and support categories, and individual cost elements (SC(N), N=1, 2, ..., 11). The percentage of total LCC is computed and displayed for each cost element and for the acquisition and support cost categories.

A list of cost element names and the percentage* of each that is allocated to the acquisition cost category are shown at the conclusion of the table.

Table 16: Terminal Costs - Ranked by LCC

The focus of Table 16 is on costs which have been collected at or aggregated to the terminal level of WBS indenture. Terminal costs are presented by cost element and aggregated to a total terminal LCC.

The terminal type names, listed in order of descending magnitude of terminal LCC, are displayed in the leftmost column of the table. The next seven columns display costs for each terminal type by cost element.** The column entitled "O&S" lists the total of the O&S costs allocated to each terminal type. The O&S figure is computed by the formula $\sum_{N=1}^{7} OSP(N)SC(N,K)$ where SC(N,K) is the allocation of SC(N) to terminal type K; the TOTAL column represents the quantity $\sum_{N=1}^{7} SC(N,K)$.

---

*These percentages represent the quantities (1-OSP(N)), where an OSP(N) factor is the fraction of each cost element SC(N) that is to be allocated to the operations and support cost. The OSP(N) factors are used in cost calculations displayed in Tables 16-18.

**The column for Cost Element 3 contains all zeros because maintenance bench sets were not used in this sample model run. The column for Cost Element 7, Support Equipment, is zero because the model no longer prorates SE to terminal types. (See text of Cost Element 7 for documentation of a former version of the model which prorated SE to terminal types.)

"PCT" is the percentage of total system LCC that each terminal LCC represents. The "QUAN" column shows the number of terminals purchased of each type. Finally, the "LCC/TERM" column entries represent the quantity [TOTAL/QUAN].

Cost Elements 8-11 are not included in this table since they are computed at the total system level.

Table 17: LRU Costs - Ranked by LCC

Table 17 applies the format used in Table 16 to LRUs.* Items are listed in descending order of magnitude based on Total LCC per LRU, $\sum_{N=1}^{8} SC(N,I)$, where SC(N,I) is the allocation of SC(N) to LRU type I. (This quantity is displayed under the heading TOTAL.) LCCs for each LRU are allocated to eight cost element components. O&S costs and FAILS, the total number of failures over the life cycle by LRU type (XFL(I) in the notation of the text), are also shown for each LRU. O&S costs are allocated to individual LRUs, using the same OSP(N) factors, by the formula $\sum_{N=1}^{8} OSP(N)SC(N,I)$. The *LCC/FAILS is calculated* by the expression [TOTAL/FAILS].

Table 18: LRU Costs - Unranked

Table 18 contains the same information that is shown in Table 17. However, for the convenience of the user, LRU data are presented in order of LRU index number (as opposed to being sorted on the basis of LCC magnitude).

---

*For explanation of the zero entries in the columns of Cost Elements 3 and 7, see preceding footnote with discussion of Table 16.

Table Number and Title(s)	LRU Type	Terminal Type	Environment	Site	SE Item	Cost Element
			Information Presented By:			
INPUT SECTION						
- Miscellaneous Parameter Values	I	I	I	I	I	
1. Quantity of Terminal Type By Site		I		I		
2. Predicted Average Terminal Operating Hours		I		I		
3. LRU Reference Table	I					
4. LRU Quantities by Terminal Type	I	I				
5. LRU Operation & Support Parameters	I					
6. Predicted LRU MTBF by Environment	I		I			
7. Reliability K Factor by Environment			I			
8. SE Cost by SERD Number					I	
Total SE Hardware Acquisition Cost					C	
9. LRU-SE Usage Matrix	I				I	
OUTPUT SECTION						
10. No. of Required Spares by Site by LRU	N			N		
Expected Failures/Month	N			N		
11. Expected Repair Hours/Month for All LRUs	N			N		
No. of LRUs of Type I by Site	I			I		
12. Availability, Mean Down Time, and MTBD for Terminal K by Site		N		N		
13. Required SE Items to be Purchased				N	N	
Expected SE Utilization				N	N	
14. Required Men to Be Trained	I/N					
15. Systems Cost						C
16. Terminal Costs - Ranked by LCC		C				C
17. LRU Costs - Ranked by LCC	C					C
18. LRU Costs - Unranked	C					C

KEY

I = Input Values

C = Cost Calculation

N = Non-Cost Calculation

Exhibit 6. AFSATCOM LCC Model Output Table Directory

DATE: 06/18/76

```
********************************
*                              *
*   SITE  LIFE  CYCLE  COST    *
*                              *
********************************

********************************
*                              *
*       INPUT  SECTION         *
*                              *
********************************
```

Exhibit 7. Sample Output Reports from the AFSATCOM LCC Model

MISCELLANEOUS PARAMETER VALUES

```
$SYS
ACPP=224.61, BAA=140, BLR=11.72, BMF=3.12, CON=1, DAA=147,
DLR=16.347, DMF=2.5, EBO=0.1, KB=1.02, KD=1.1,
NEXP=0, NQPA=132, NT=15, OPT=5,
PAL=177.37, PIUP=10, PSC=.78, PSO=.99, SA=20.20, SEEF=1.000,
TCMW=163.52, TDU=8., TRANB(1)=.25,.75, TRAND(1)=120,240, TRD=.15,
CONSOL(1) = 'A1','A2','A3','00','B1','B2','B3','C1','00','B4',
'B5','B6','C2','00','B7','B8','B9','C3','00'
N1=3, N2=27, N3=49, UCF=1.3120,
$END
$LCC
AGEOPT=0, AMA(1)=171*.07, BRCT=.23,CRCT=.46, DRCT=.7, OST(1)=1.5,1.5,
IBS(1)=132*1, IMC=145.11, IMH(1)=132*0,KC=1.12, MCOTT(1)=30*0, MD=2,
A25(1)=0,0,0,0,0,B25(1)=0,0,0,0,0, KPRINT=6,
MFAC(1)=1.3,1.5,2.6, MMTD=15, MNT=30,N=23,
OSP(1)=0.,0.,1.,1.,0.9,1.,1.,0.,1.,0.9,1.,0.,
NA=171,NRL=3,NRT=0.01,RIP=132*0, SMH(2)=.5, SMH(9)=3*.5, SMH(38)=.5,
SMH(45)=.5,SMH(44)=.5,PWR(1)=1.2850,1.4360,
SMI(2)=6, SMI(9)=3,6,6, SMI(38)=6, SMI(45)=3, TCMB=12907.,SMI(44)=3,
TCMD=12907., TDAP(1)=171*0, TDAP(2)=75, TDAP(22)=88, TDAP(116)=156,
TDP=4.23, TDSP=110, TDTP(1)=30*0, TE=0, TOPI=100000,
TOPR=35000,T1=9500, XUC=1.3120, WOR=.001, TRANC=.75,
XFEE=1.0,XGA=1.0,RLC=1.00, OFLG(1)='Z','Z','Z',
$END
```

Exhibit 7 (continued)

TABLE 1

QUANTITY OF TERMINAL TYPE BY SITE (IT)

			TERMINAL TYPE														
#	SITE	LO	B52	ESA	RC5	1A	2	2R	3	4	TAC	9	12	14A	LCC	WCP	UNIQUE 13
1	A1	US3	5	0	0	6	7	0	0	0	0	0	0	0	0	1	
2	A2	US3	5	0	0	6	7	0	0	0	0	0	0	0	0	1	
3	A3	US3	5	0	0	6	7	0	0	0	0	0	0	0	0	1	
4	B1	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
5	B2	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
6	B3	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	SWP
7	C1	OSO	0	3	0	0	4	0	0	0	0	2	0	1	0	0	
8	B4	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
9	B5	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
10	B6	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	8A
11	C2	OSO	0	3	0	0	4	0	0	0	0	2	0	1	0	0	
12	B7	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
13	B8	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
14	B9	OSO	0	0	2	0	0	2	0	0	0	0	0	1	0	0	
15	C3	OSO	0	3	0	0	4	0	0	0	0	2	0	1	0	0	

Exhibit 7 (continued)

TABLE 2

PREDICTED AVERAGE TERMINAL OPERATING HOURS/MONTH (ATOH)

#	SITE	B52	ESA	RCS	1A	2	2B	3	4	TAC	9	12	14A	LCC	MCP	UNIQUE
		TERMINAL TYPE														
1	A1	84.	0.	0.	123.	104.	0.	0.	0.	0.	0.	0.	0.	0.	730.	92.
2	A2	84.	0.	0.	123.	104.	0.	0.	0.	0.	0.	0.	0.	0.	730.	0.
3	A3	84.	0.	0.	123.	104.	0.	0.	0.	0.	0.	0.	0.	0.	730.	0.
4	B1	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
5	B2	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
6	B3	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	234.
7	C1	0.	147.	0.	0.	8.	0.	0.	0.	0.	147.	0.	0.	0.	0.	0.
8	B4	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
9	B5	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
10	B6	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	146.
11	C2	0.	147.	0.	0.	8.	0.	0.	0.	0.	147.	0.	0.	0.	0.	0.
12	B7	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
13	B8	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
14	B9	0.	0.	129.	0.	0.	129.	0.	0.	0.	0.	0.	74.	0.	0.	0.
15	C3	0.	147.	0.	0.	8.	0.	0.	0.	0.	147.	0.	0.	0.	0.	0.

Exhibit 7 (continued)

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

TABLE 3

LRU REFERENCE TABLE

LRU (I)	LRU NAME	WUC	PART NUMBER	MBS	REPAIR LEVEL 1	REPAIR LEVEL 2	REPAIR LEVEL 3	LRU PRICE BASE	LRU PRICE ESC. LC.	LRU PRICE G & A	LRU PRICE FEE	QTY
1	ANTENNA,AS-3061/G, GND, 6DB	*AA00	622-1618-001	0	DR	DR	DR	6292.	8255.	8255.	8255.	15.
2	ANTENNA,AS-3060/G, GND, 14DB	*AA00	622-1619-001	0	DR	DR	BR	15840.	20782.	20782.	20782.	52.
3	DRIVE,ANT,TG-227/G,AUTOMATIC	*AB00	622-1620-001	0	DR	BR	BR	16978.	22275.	22275.	22275.	51.
4	DIPLEXER, CU-2126/U	AD00	622-1567-001	0	BD	BD	BD	2950.	3870.	3870.	3870.	10.
5	AMPLIFIER, RF, AM-6728/U	*AE00	622-1705-001	0	BD	DR	BR	408.	535.	535.	535.	148.
6	AMP,RAD FREQ,AM-6729/U,DIST	*AT00	622-1706-001	0	BD	DR	BR	441.	579.	579.	579.	38.
7	1MHZ DIVIDER (RF MON TIMING)	AM00	277-0431-010	0	BD	BD	BD	77.	101.	101.	101.	13.
8	COMBINER,3-WAY	AL00	277-0430-010	0	BD	BD	BD	1466.	1923.	1923.	1923.	9.
9	RT RADIO AN/ARC-171(U) 1A DC	*KA00	622-1559-001	0	BR	BR	BR	15910.	20874.	20874.	20874.	33.
10	RT RADIO AN/ARC-171(U) 1H DC	*KA00	622-1566-001	0	BR	BR	BR	13077.	17157.	17157.	17157.	0.
11	RT RADIO AN/ARC-171(U) 1A AC	*KA00	622-1884-001	0	BR	BR	BR	15234.	19987.	19987.	19987.	99.
12	RT RADIO AN/ARC-171(U) 1H AC	*KA00	622-2143-001	0	BR	BR	BR	13101.	17189.	17189.	17189.	135.
13	HIGH POWER AMP AM-6727/A	*KB00	622-1569-001	0	DR	DR	DR	12532.	16442.	16442.	16442.	0.
14	PA POWER SUPPLY PP-7118/A	*KC00	622-1570-001	0	DR	DR	DR	5302.	6956.	6956.	6956.	0.
15	MTG BASE ELCT EQUIP MT4714/A	*	622-1571-001	0	BR	BR	BD	1698.	2228.	2228.	2228.	0.
16	MODEM, TELETYPE, MD-953/U	*KD00	622-1513-001	0	BR	BR	BR	7680.	10076.	10076.	10076.	98.
17	MODEM, TELETYPE, FSK AFC	*KD00	622-1692-001	0	BR	BR	BR	8913.	11694.	11694.	11694.	18.
18	MODEM, TTY, MD-951/U FSK 1X3	*KE00	622-1514-001	0	BR	BR	BR	8550.	11218.	11218.	11218.	85.
19	MODEM, TTY, MD-952/U (WB)	*KF00	622-1517-001	0	BR	BR	BR	22260.	29205.	29205.	29205.	50.
20	SYNCHRONIZER, FORCE,C-9685/U	*EB00	622-1936-001	0	DR	BR	BR	4730.	6206.	6206.	6206.	50.
21	SYNCHRONIZER, COMD, C-9691/U	*EB00	622-1937-001	0	DR	BR	BR	6602.	8662.	8662.	8662.	32.
22	POWER SUPPLY, PP-7121/U(SYN)	*ED00	622-1938-001	0	DR	DR	BR	950.	1246.	1246.	1246.	96.
23	RT RADIO AN/ARC-171(U) 1P	*KA00	622-1564-001	0	BR	BR	BR	13200.	17318.	17318.	17318.	93.

NOTE:

WUC - WORK UNIT CODE

REPAIR LEVEL

1 = CRC
2 = IMP
3 = CIMP

REPAIR LEVEL CODE

DR - DEPOT REPAIR
BR - INTERMEDIATE REPAIR
BD - INTERMEDIATE DISCARD

Exhibit 7 (continued)

TABLE 4

LRU QUANTITIES BY TERMINAL TYPE (QPA)

LRU	TERMINAL TYPE																													
	B52	E5A	RC5	1A	2	2B	3	4	TAC	9	12	14A	LCC	WCP	5	5D	6	8A	13	ATC	SWP	C-1	C-3	C-9	E-1	E-3	E-12	P-2	P-8	P-11
LE	3	3	3	3	3	3	3	3	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1
1	0	0	0	0	0	0	0	0	0	2	0	0	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	1	2	2	4	0	8	2	4	4	4	4	4	4	0
3	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	1	2	1	1	0	8	2	4	4	3	4	4	4	0
4	0	0	0	0	0	0	1	1	0	1	2	0	0	0	1	2	1	2	2	0	0	0	2	0	0	2	0	0	0	1
5	1	1	1	1	1	1	1	1	0	1	2	2	1	1	1	1	1	2	2	2	0	4	2	2	2	2	2	2	2	1
6	0	0	0	0	0	0	1	1	0	1	2	2	0	0	0	0	1	2	2	2	0	4	1	2	2	2	2	2	2	0
7	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	2	1	1	1	1	1	1	1	0
8	0	0	0	0	0	0	1	1	0	1	3	0	0	0	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	2	1	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	5	4	2	1	5	10	0	0	1	2	0	4	5	10	0	20	4	10	8	5	6	8	10	1
13	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	1	1	0	1	1	2	2	0	0	2	0	1	1	0	0	1	0	2	0	0	0	0	0	0	2	0	0	0	0
17	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	3	0	1	1	3	6	0	0	1	2	1	4	3	6	0	20	2	6	10	3	4	10	10	1
19	0	0	0	0	0	0	2	2	1	0	2	4	0	0	0	0	0	0	2	4	0	8	2	4	2	2	2	2	4	0
20	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	1	0	0	1	1	2	0	0	0	0	0	0	1	2	1	4	0	2	0	1	2	2	1	0
22	1	1	1	1	0	0	1	0	0	1	1	2	1	1	0	0	0	2	1	2	0	4	0	2	0	1	2	0	1	0
23	1	1	1	1	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Exhibit 7 (continued)

TABLE 5

LRU OPERATION & SUPPORT PARAMETERS

LRU	ASEC	TW	UP	WT	RT	RMH	PA	TDLP	RTS	NRTS	COND
1	282.	0.0	8255.	40.	0.80	0.7500	5	0.0	0.0	0.999	0.001
2	345.	0.0	20782.	75.	1.18	0.7500	9	0.0	0.989	0.010	0.001
3	258.	0.0	22275.	95.	1.40	0.4720	2	0.0	0.989	0.010	0.001
4	0.	0.0	3870.	48.	0.0	0.7360	0	0.0	0.0	0.0	1.000
5	87.	0.10	535.	3.	3.94	0.5380	0	0.0	0.989	0.010	0.001
6	98.	0.10	579.	4.	3.94	0.5330	0	0.0	0.989	0.010	0.001
7	0.	0.0	101.	5.	0.0	0.7500	0	0.0	0.0	0.0	1.000
8	0.	0.0	1923.	21.	0.0	0.7500	0	0.0	0.0	0.0	1.000
9	904.	0.60	20874.	32.	0.70	0.1670	8	0.0	0.989	0.010	0.001
10	727.	0.50	17157.	32.	0.54	0.3870	5	0.0	0.989	0.010	0.001
11	863.	0.60	19987.	32.	0.70	0.1670	2	0.0	0.989	0.010	0.001
12	727.	0.50	17189.	32.	0.64	0.3850	5	0.0	0.989	0.010	0.001
13	1236.	0.20	16442.	40.	1.66	0.4830	4	0.0	0.0	0.999	0.001
14	1113.	0.10	6956.	45.	0.80	0.4810	1	0.0	0.0	0.999	0.001
15	83.	0.0	2228.	25.	0.54	0.7500	0	0.0	0.0	0.0	1.000
16	604.	0.20	10076.	15.	0.72	0.3560	8	0.0	0.989	0.010	0.001
17	1142.	0.50	11694.	17.	1.08	0.1670	1	0.0	0.989	0.010	0.001
18	376.	0.30	11218.	27.	1.12	0.3670	6	0.0	0.989	0.010	0.001
19	1072.	0.60	29205.	25.	1.24	0.4050	19	0.0	0.989	0.010	0.001
20	510.	0.30	6206.	12.	0.88	0.2670	5	0.0	0.989	0.010	0.001
21	644.	0.30	8662.	12.	0.80	0.4660	6	0.0	0.989	0.010	0.001
22	199.	0.10	1246.	13.	0.51	0.1670	3	0.0	0.989	0.010	0.001
23	862.	0.60	17318.	32.	0.70	0.1670	2	0.0	0.989	0.010	0.001

TW - PLANNED TECHNICAL TRAINING (WEEKS/MAN/LRU)
UC - LRU UNIT BUY PRICE ($/LRU)
WT - LRU WEIGHT (LBS/LRU)
RT - LRU REPAIR TIME, OFF-LINE (MANHOURS/LRU FAILURE)
RMH - REMOVE AND REPLACE TIME, ON-LINE (MANHOURS/LRU FAILURE)
PA - LRU ASSEMBLIES NEW TO INVENTORY (NEW ASSEMBLIES/LRU)
TDLP - PLANNED TECHNICAL DATA (PAGES/LRU)
RTS - PROPORTION OF FAILURES REPAIRED AT BASE
NRTS - PROPORTION OF FAILURES REPAIRED AT DEPOT
COND - PROPORTION OF FAILURES DISCARDED

Exhibit 7 (continued)

TABLE 6

PREDICTED LRU MTBF BY ENVIRONMENT

LRU	GRD, FIX(30 C)	GRD,TRAN(30 C)	ARMN(40 C)
1	6290000.	0.	0.
2	1820000.	1370000.	0.
3	115000.	85000.	0.
4	149000.	112000.	50000.
5	173000.	131000.	98000.
6	197000.	150000.	110000.
7	900000.	900000.	0.
8	900000.	900000.	900000.
9	4904.	3687.	2000.
10	6200.	4600.	0.
11	4964.	3732.	2050.
12	6700.	5000.	2500.
13	0.	0.	8900.
14	0.	0.	12000.
15	0.	0.	48000.
16	8900.	7300.	3200.
17	0.	0.	2600.
18	4100.	3100.	1400.
19	4300.	3200.	1500.
20	8000.	0.	3450.
21	7400.	5600.	3000.
22	77000.	58000.	24000.
23	0.	0.	1600.

Exhibit 7 (continued)

AD-A056 102 MITRE CORP BEDFORD MASS F/G 15/5
AFSATCOM LIFE CYCLE COST MODEL, (U)
JUN 78 J H JAMES, W M STEIN F19628-77-C-0001
UNCLASSIFIED MTR-3057 ESD-TR-78-114 NL

2 OF 2
AD
A056 102

END
DATE
FILMED
8-78
DDC

TABLE 7

RELIABILITY K FACTOR BY ENVIRONMENT(MFAC)

GRD, FIX(30 C)	GRD, TRAN(30 C)	ARBN (40 C)
MFAC(1)	MFAC(2)	MFAC(3)
1.30	1.50	2.60

Exhibit 7 (continued)

TABLE 8

SE COST BY SERD NUMBER

SERD	DESCRIPTION		IPL	COST 1 N<= 3	COST 2 N<= 27	COST 3 N<= 49	COST 4 N>= 50
1	UHF R/T TEST PANEL	622-1636-001	0	34767.	18160.	12043.	10195.
2	SYNCHRONIZER TEST PANEL	622-1644-001	0	35158.	19584.	13043.	11017.
5	NARROW BAND MODEM TEST PANEL	622-1643-001	0	31466.	16131.	12256.	8479.
21	ANTENNA POSITIONER TEST SET	622-1723-001	0	20361.	8688.	5139.	4241.
23	WIDEBAND MODEM TEST PANEL	622-1645-001	0	31221.	14994.	9211.	7624.
25	POWER SUPPLY TEST SET	622-1748-001	0	14934.	5971.	3494.	2776.
26	POWER AMPLIFIER TEST SET	622-1749-001	0	24521.	10102.	5736.	4593.
27	POWER SUPPLY TEST SET	622-1780-001	0	15735.	6903.	4119.	3351.
28	ELECTRONIC TEST EXTENDER SET	622-1765-001	1	1140.			
29	ELECTRONIC TEST EXTENDER SET	622-1763-001	0	6089.	2162.	1870.	1539.
30	ELECTRONIC TEST EXTENDER SET	622-1764-001	0	6285.	1860.	929.	684.
32	ELECTRONIC TEST EXTENDER SET	622-1767-001	0	4839.	1614.	924.	731.
41	RF TEST SET	BIRD 43	1	128.			
42	DETECTING ELEMENT	BIRD 25D	1	35.			
43	DETECTING ELEMENT	BIRD 50D	1	37.			
44	DETECTING ELEMENT	BIRD 250D	1	39.			
45	ELECTRICAL DUMMY LOAD	BIRD 8135	1	69.			
46	OSCILLOSCOPE	MIL-C-9960C	1	2965.			
47	MULTIMETER	HP 410C	1	860.			
50	DIGITAL MULTIMETER	FLUKE 8100A	1	765.			
51	COUNTER AND PLUG IN	HP5360A/5379A	1	8885.			
52	SIGNAL GENERATOR	AN/USM-323	1	3238.			
55	AUDIO LEVEL METER	1840-9701	1	544.			
56	ATTENUATOR	CN-1239/U	1	14.			
57	RF VOLTMETER	BOONTON 92A	1	967.			
58	SPECTRUM ANALYZER	AN/USM-259	1	878.			
59	SPECTRUM ANALYZER	HP 141T	1	2627.			
60	ADJUSTER ATTENUATOR	GR 874-GAL	1	190.			
61	WIDE BAND MODEM	622-1517-001	19	29205.			
62	FSK MODUM-BW/AFC	622-1692-001	17	11694.			
67	RT GROUP OR-146/A	622-1559-001	9	20874.			
68	MODEM TELEGRAPH MD 951/U	622-1514-001	18	11218.			
69	DOUBLE BALANCED MIXER	HP-10514A	1	107.			
81	RF POWER AMPLIFIER	HP 230B	1	1505.			
83	POWER METER	HP-432A	1	747.			
85	VARIABLE ATTENUATOR	CN-970/U	1	122.			
86	VARIABLE ATTENUATOR	CN-1128/U	1	190.			
88	RADIO FREQUENCY BOLOMETER	HP-478A	1	122.			
89	POWER SUPPLY	HP-6269A	1	1061.			
90	HETRODYNE CONVERTER	HP-5253B	1	997.			
91	POWER SUPPLY	HP-6205B	1	351.			
93	CRYSTAL DETECTOR	HP 423A OP-2	1	225.			
94	IF SECTION	HP-8552B	1	8346.			
95	TUNING SECTION	HP-8554B	1	4386.			
104	TELETYPEWRITER TEST SET	PD-SANE-96C	1	3202.			
105	DETECTING ELEMENT	BIRD-5D	1	42.			
106	SPECIAL PURPOSE CABLE ASSY. ELEC	622-2047-001	0	3896.	861.	268.	184.
122	WAVEFORM GENERATOR	WAVETEX 116	1	1338.			
123	SIGNAL AND NOISE COMBINER	623-2320-001	0	10575.	7050.	5252.	4462.
127	QUARTZ OSCILLATOR	HP 105 B	1	3011.			
143	SERIAL DATA GENERATOR	662-2601-001	0	70372.	27810.	16827.	12934.
150	RF SECTION	HP8553B	0	0.	0.	0.	0.
153	AC VOLT METER	HP 400 D	1	351.			
154	LOGIC ANALYZER	HP 500 A	1	2580.			
155	STABILIZED RF RATIO-METER	WEIN 1810	1	593.			
156	THERMISTOR MOUNT	GM N401A	1	125.			
157	BARRETTER ELEMENT	GM 408 A	1	18.			
158	AUDIO INTERFERENCE SUPPRESSOR	NARDA 562	1	80.			
159	VSWR BRIDGE	WILTRON60G50	1	475.			
160	PRECISION STEP ATTENUATOR	WEINSCHEL60S	1	1000.			
161	RESISTIVE TERMINATION	GR 874 W50BL	1	40.			
162	PULSE GENERATOR	DP 110B	1	1512.			

TOTAL SE HARDWARE ACQUISITION COST	1517375.
PECULIAR SE HARDWARE ACQUISITION COST	1090703.
PECULIAR SE LRU ACQUISITION COST	364952.
COMMON SE HARDWARE ACQUISITION COST	426672.

Exhibit 7 (continued)

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

TABLE 9

LRU-SR USAGE MATRIX (A)

```
LRU

  1   18   1  41  43  46  50  51  52  59  67  89  94  95 105 122 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  2   18   1  41  43  46  50  51  52  59  67  89  94  95 105 122 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  3    4  21  47  50 153
           1   1   1   1
  4   20   1  41  43  45  46  50  51  52  57  59  67  89  94  95 106 122 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  5   17   1  46  50  51  52  59  67  89  91  94  95 106 122 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  6   17   1  46  50  51  52  59  67  89  91  94  95 106 122 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  7    3  45  52  57
           1   1   1
  8    5  45  50  52  57 106
           1   1   1   1   1
  9   37   1  25  26  29  41  43  44  45  46  47  50  51  52  55  56  57  58  59  60  67  69  81  83  88  89  90  91  93  94  95
         105 122 127 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1   1   1   1
 10   34   1  25  26  29  41  44  45  46  47  50  51  52  56  57  59  60  67  69  81  83  88  89  90  91  94  95 105 122 127 143
         153 154 162 170
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1
 11   37   1  25  26  29  41  43  44  45  46  47  50  51  52  55  56  57  58  59  60  67  69  81  83  88  89  90  91  93  94  95
         105 122 127 143 153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1   1   1   1
 12   33   1  25  26  29  41  44  45  46  47  50  51  52  56  57  59  60  67  69  81  83  88  89  90  91  94  95 105 122 127 143
         153 154 162
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1
 13   26   1   3  35  40  41  44  46  47  48  50  51  52  57  59  65  67  89  91  94  95 122 143 153 154 162 167
           1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 14   11   7  46  50  63  69  87  89 122 164 165 167
           1   1   1   1   1   1   1   1   1   1   1
 15    0   0
           0
 16   36   5  27  30  46  47  50  51  52  59  62  68  83  85  86  88  89  91  94  95 104 122 123 127 143 155 156 157 158 159 160
         161 163 164 165 166 171
           1   1   1   1   1   1   1   1   1   1   1   1   2   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1   1   1
 17   36   5  27  30  46  47  50  51  52  59  62  68  83  85  86  88  89  91  94  95 104 122 123 127 143 155 156 157 158 159 160
         161 163 164 165 166 171
           1   1   1   1   1   1   1   1   1   1   1   1   2   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1   1   1
 18   36   5  27  30  46  47  50  51  52  59  62  68  83  85  86  88  89  91  94  95 104 122 123 127 143 155 156 157 158 159 160
         161 163 164 165 166 171
           1   1   1   1   1   1   1   1   1   1   1   1   2   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
           1   1   1   1   1   1
```

Exhibit 7 (continued)

Table 9 (continued)

19	35	23	27	32	46	47	50	51	52	59	61	83	85	86	88	89	94	95	104	122	123	127	143	150	155	156	157	158	159	160	161
		163	164	165	166	171																									
		1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1																									
20	10	2	28	46	50	51	85	91	127	143	154																				
		1	1	1	1	1	1	1	1	1	1																				
21	10	2	28	46	50	51	85	91	127	143	154																				
		1	1	1	1	1	1	1	1	1	1																				
22	8	27	46	50	89	163	164	165	166																						
		1	1	1	1	1	1	1	1																						
23	38	1	25	26	29	41	42	43	45	46	47	50	51	52	55	56	57	58	59	60	67	69	81	83	88	89	90	91	93	94	95
		105	122	127	143	153	154	162	170																						
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1																						
24	7	9	46	50	51	107	114	143																							
		1	1	1	1	1	1	1																							
25	11	19	22	46	50	80	108	109	124	125	135	152																			
		1	1	1	1	1	1	1	1	1	1	1																			
26	13	19	22	46	50	80	102	108	109	111	124	125	135	152																	
		1	1	1	1	1	1	1	1	1	1	1	1	1																	
27	11	22	46	50	124	125	129	146	147	148	149	151																			
		1	1	1	1	1	1	1	1	1	1	1																			
28	5	22	46	50	124	125																									
		1	1	1	1	1																									
29	5	22	46	50	124	125																									
		1	1	1	1	1																									
30	5	22	46	50	124	125																									
		1	1	1	1	1																									
31	10	22	46	50	51	122	124	125	129	136	137																				
		1	1	1	1	1	1	1	1	1	1																				
32	11	22	27	46	50	89	124	125	163	164	165	166																			
		1	1	1	1	1	1	1	1	1	1	1																			
33	11	22	27	46	50	89	124	125	163	164	165	166																			
		1	1	1	1	1	1	1	1	1	1	1																			
34	6	9	46	50	51	98	143																								
		1	1	1	1	1	1																								
35	8	46	50	104	110	118	119	132	138																						
		1	1	1	1	1	1	1	1																						
36	5	46	50	110	117	118																									
		1	1	1	1	1																									
37	0	0																													
		0																													
38	8	9	15	26	46	50	51	91	143																						
		1	1	1	1	1	1	1	1																						
39	7	9	11	38	46	50	51	143																							
		1	1	1	1	1	1	1																							
40	7	9	11	38	46	50	51	143																							
		1	1	1	1	1	1	1																							
41	7	9	12	38	46	50	51	143																							
		1	1	1	1	1	1	1																							
42	7	9	12	37	46	50	51	143																							
		1	1	1	1	1	1	1																							
43	6	9	14	46	50	51	143																								
		1	1	1	1	1	1																								
44	7	9	10	34	46	50	51	143																							
		1	1	1	1	1	1	1																							
45	8	9	10	34	46	50	51	117	143																						
		1	1	1	1	1	1	1	1																						

Exhibit 7 (continued)

Table 9 (continued)

46	14	46	47	50	51	52	57	59	81	90	91	94	95	96	170						
		1	1	1	1	1	1	1	2	1	1	1	1	1	1						
47	7	9	18	46	50	51	52	143													
		1	1	1	1	1	1	1													
48	4	21	47	50	153																
		1	1	1	1																
49	1	50																			
		1																			
50	9	9	16	33	46	50	51	52	106	143											
		1	1	1	1	1	1	1	1	1											
51	7	9	20	46	47	50	51	143													
		1	1	1	1	1	1	1													
52	20	1	41	43	45	46	50	51	52	57	59	67	89	94	95	106	122	143	153	154	162
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
53	5	50	52	57	91	106															
		1	1	1	1	1															
54	6	46	47	50	63	92	96														
		1	1	1	1	1	1														
55	6	8	46	50	58	63	163														
		1	1	1	1	1	1														
56	1	121																			
		1																			
57	6	9	46	50	51	64	143														
		1	1	1	1	1	1														
58	3	46	50	112																	
		1	1	1																	
59	3	46	50	112																	
		1	1	1																	
60	0	0																			
		0																			
61	0	0																			
		0																			
62	0	0																			
		0																			
63	0	0																			
		0																			
64	0	0																			
		0																			
65	1	50																			
		1																			
66	1	50																			
		1																			
67	1	50																			
		1																			
68	1	50																			
		1																			
69	18	1	41	43	46	50	51	52	59	67	89	94	95	105	122	143	153	154	162		
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
70	1	50																			
		1																			
71	5	50	52	57	91	106															
		1	1	1	1	1															
72	18	1	41	43	46	50	51	52	59	67	89	94	95	105	122	143	153	154	162		
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
73	11	2	46	50	51	85	86	91	115	127	143	154									
		1	1	1	1	1	1	1	1	1	1	1									

Exhibit 7 (continued)

Table 9 (concluded)

74	13	19	46	50	104	108	110	117	119	139	140	141	142	169							
		1	1	1	1	1	1	1	1	1	1	1	1	1							
75	1	115																			
		1																			
76	1	50																			
		1																			
77	3	45	52	57																	
		1	1	1																	
78	3	45	52	57																	
		1	1	1																	
79	5	50	52	57	91	106															
		1	1	1	1	1															
80	5	50	52	57	91	106															
		1	1	1	1	1															
81	0	0																			
		0																			
82	20	1	41	43	45	46	50	51	52	57	59	67	89	94	95	106	122	143	153	154	162
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
121	5	50	52	57	91	106															
		1	1	1	1	1															
128	1	131																			
		1																			
129	1	130																			
		1																			
130	1	133																			
		1																			
131	1	134																			
		1																			
132	1	145																			
		1																			

Exhibit 7 (continued)

DATE: 06/18/76

SITE LIFE CYCLE COST

OUTPUT SECTION

Exhibit 7 (continued)

```
                                        TABLE 10

NO. OF REQUIRED SPARES BY SITE BY LRU                                  EXPECTED FAILURES PER HOURS

                    SPARING ACCORDING TO EXPECTED BACKORDER REQUIREMENT (EBO)
          (READ SITES LEFT TO RIGHT, TOP DOWN IN ORDER OF SITES LISTED IN TABLES 1 AND 2)

LRU   1 TOTAL SPARES =      0.

LRU   2 TOTAL SPARES =      0.

LRU   3 TOTAL SPARES =      0.

LRU   4 TOTAL SPARES =      0.

LRU   5 TOTAL SPARES =      6.
         1   1   1   0   0   0   1   0   0                  0.06  0.06  0.06  0.01  0.01  0.01  0.01  0.01  0.01
         0   1   0   0   0   1                        0.02  0.01  0.01  0.01  0.01  0.01

LRU   6 TOTAL SPARES =      0.

LRU   7 TOTAL SPARES =      0.

LRU   8 TOTAL SPARES =      0.

LRU   9 TOTAL SPARES =      6.
         1   1   1   0   0   0   1   0   0                  0.94  0.94  0.94  0.0   0.0   0.0   0.04  0.0   0.0
         0   1   0   0   0   1                        0.0   0.04  0.0   0.0   0.0   0.04

LRU  10 TOTAL SPARES =      0.

LRU  11 TOTAL SPARES =     33.
         1   1   1   2   2   2   4   2   2                  1.66  1.66  1.66  0.98  0.98  0.98  0.56  0.98  0.98
         2   4   2   2   2   4                        0.98  0.56  0.98  0.98  0.98  0.56

LRU  12 TOTAL SPARES =     13.
         1   0   0   1   1   1   1   1   1                  0.09  0.0   0.0   0.14  0.14  0.14  0.06  0.14  0.14
         1   1   1   1   1   1                        0.26  0.06  0.14  0.14  0.14  0.06

LRU  13 TOTAL SPARES =      0.

LRU  14 TOTAL SPARES =      0.

LRU  15 TOTAL SPARES =      0.

LRU  16 TOTAL SPARES =     18.
         1   1   1   1   1   1   2   1   1                  1.06  1.06  1.06  0.42  0.42  0.42  0.38  0.42  0.42
         1   2   1   1   1   2                        0.42  0.38  0.42  0.42  0.42  0.38

LRU  17 TOTAL SPARES =      4.
         1   1   1   0   0   0   1   0   0                  0.74  0.74  0.74  0.0   0.0   0.0   0.0   0.0   0.0
         0   0   0   0   0   0                        0.0   0.0   0.0   0.0   0.0   0.0

LRU  18 TOTAL SPARES =     13.
         1   0   0   1   1   1   1   1   1                  0.09  0.0   0.0   0.14  0.14  0.14  0.09  0.14  0.14
         1   1   1   1   1   1                        0.33  0.09  0.14  0.14  0.14  0.09

LRU  19 TOTAL SPARES =     13.
         1   0   0   1   1   1   1   1   1                  0.09  0.0   0.0   0.09  0.09  0.09  0.0   0.09  0.09
         1   1   1   1   1   1                        0.09  0.0   0.09  0.09  0.09  0.0

LRU  20 TOTAL SPARES =     15.
         1   1   1   1   1   1   1   1   1                  0.12  0.12  0.12  0.19  0.19  0.19  0.38  0.19  0.19
         1   1   1   1   1   1                        0.24  0.38  0.19  0.19  0.19  0.38

LRU  21 TOTAL SPARES =     12.
         0   0   0   1   1   1   1   1   1                  0.02  0.0   0.0   0.03  0.03  0.03  0.05  0.03  0.03
         1   1   1   1   1   1                        0.03  0.05  0.03  0.03  0.03  0.05

LRU  22 TOTAL SPARES =     15.
         1   1   1   1   1   1   1   1   1                  0.14  0.14  0.14  0.03  0.03  0.03  0.05  0.03  0.03
         1   1   1   1   1   1                        0.08  0.05  0.03  0.03  0.03  0.05

LRU  23 TOTAL SPARES =     21.
         2   2   2   1   1   1   2   1   1                  1.06  1.06  1.06  0.42  0.42  0.42  0.77  0.42  0.42
         1   2   1   1   1   2                        0.42  0.77  0.42  0.42  0.42  0.77

  TOTAL SPARES AT DEPOT BY LRU
  (READ TABLE LEFT-RIGHT, TOP-DOWN)
  (SPARING INCLUDES DEPOT SPARING AND FRACTIONAL SPARES NOT ASSIGNED TO SITES)

         0   0   0   0   0   0   0   0   1
     0   1   1   0   0   0   1   1   1   0
     1   0   0   1   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0
```

Exhibit 7 (continued)

TABLE [illegible]

EXPECTED REPAIR HRS. PER MONTH FOR ALL LRUS BY SITE

(READ EACH TABLE LEFT TO RIGHT, TOP DOWN IN ORDER OF LRUS LISTED IN TABLE [illegible])

SITE	I										
A1			0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.3
	10	0.0	3.6	0.2	0.0	0.0	0.0	2.4	2.5	0.2	0.0
	20	0.9	0.0	0.2	4.6						
A2			0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.3
	10	0.0	3.6	0.0	0.0	0.0	0.0	2.9	2.5	0.0	0.0
	20	0.9	0.0	0.2	4.6						
A3			0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.3
	10	0.0	3.6	0.0	0.0	0.0	0.0	2.9	2.5	0.0	0.0
	20	0.9	0.0	0.2	4.6						
B1			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B2			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B3			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.1	0.0	0.2						
C1			0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.1
	10	0.0	7.6	1.0	0.0	0.0	0.0	3.7	0.0	1.8	1.0
	20	2.6	0.3	0.2	4.4						
B4			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B5			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B6			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.3	0.0	0.0	0.0	0.5	0.0	0.4	0.1
	20	0.2	0.1	0.0	0.2						
C2			0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.1
	10	0.0	7.6	1.0	0.0	0.0	0.0	3.7	0.0	1.8	1.0
	20	2.6	0.3	0.2	4.4						
B7			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B8			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
B9			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.5	0.2	0.0	0.0	0.0	0.5	0.0	0.2	0.1
	20	0.2	0.0	0.0	0.2						
C3			0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.1
	10	0.0	7.6	1.0	0.0	0.0	0.0	3.7	0.0	1.8	1.0
	20	2.6	0.3	0.2	4.4						
[illegible]			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
	20	0.1	0.0	0.0	0.3						

NO. OF [illegible] BY SITE

SITE	I										
A1			1	2	1	4	10	2	1	3	7
	10	0	12	5	1	4	0	15	6	3	2
	20	5	3	13	14						
A2			1	0	4	4	14	0	0	0	7
	10	0	12	0	2	4	3	13	6	0	0
	20	5	0	12	14						
A3			1	0	4	4	14	0	0	0	7
	10	0	12	0	4	4	3	13	6	0	0
	20	5	5	12	14						
B1			5	4	4	4	6	2	1	5	8
	10	0	6	10	4	4	3	4	5	6	4
	20	2	2	4	4						
B2			5	4	4	4	4	2	1	5	5
	10	0	6	10	4	4	3	4	4	6	4
	20	2	2	4	4						
B3			5	4	4	4	6	2	1	5	5
	10	0	4	10	5	4	5	4	0	6	4
	20	2	3	4	4						
C1			4	4	4	2	11	4	1	2	4
	10	0	3	12	4	1	3	7	0	8	4
	20	5	4	7	7						
B4			5	4	4	4	6	2	1	5	5
	10	0	6	10	4	4	3	4	5	6	4
	20	2	2	4	4						
B5			5	4	4	4	6	2	1	5	5
	10	0	6	10	4	4	3	4	5	6	4
	20	2	2	4	4						
B6			5	4	5	4	3	4	1	5	5
	10	0	6	14	4	0	4	4	0	15	4
	20	4	2	4	4						
C2			4	4	4	4	11	4	1	2	4
	10	0	3	12	4	0	3	7	0	8	4
	20	5	4	7	7						
B7			5	4	4	4	6	2	1	5	5
	10	0	4	10	0	0	5	4	0	6	4
	20	2	2	4	4						
B8			5	4	4	4	6	2	1	5	5
	10	0	6	10	4	5	5	4	5	5	4
	20	2	2	4	4						
B9			5	4	4	4	5	2	1	5	5
	10	0	6	10	4	4	5	4	5	6	4
	20	2	2	4	4						
C3			4	4	4	2	11	4	1	2	4
	10	0	3	12	4	4	3	7	0	8	4
	20	5	4	7	7						
NUMBER OF INTERMEDIATE [illegible] WHERE LRU USED (BIS)			6	13	13	5	15	13	13	6	6
	10	0	15	13	5	4	5	15	3	13	13
	20	15	12	15	13						

Exhibit 7 (continued)

TABLE 12

AVAILABILITY, MEAN DOWN TIME, AND MTBD FOR TERMINAL X BY SITE

SITE	NS?	NSA	[illegible]	1A	2	2B	3	4	TA?	9	12	14A	[illegible]	ACP		
A1	0.99697 / 8.89 / 2929.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99812 / 4.67 / 2477.	0.99785 / 7.11 / 3292.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99955 / 1.35 / 2312.	0.99196 / 21.18 / 2561.	TT
A2	0.99697 / 8.89 / 2929.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99812 / 4.67 / 2477.	0.99785 / 7.11 / 3292.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99955 / 1.35 / 2312.	0.0 / 0.0 / 0.	
A3	0.99697 / 8.89 / 2929.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99812 / 4.67 / 2477.	0.99785 / 7.11 / 3292.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99955 / 1.35 / 2312.	0.0 / 0.0 / 0.	
B1	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B2	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B3	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99970 / 5.31 / 17731.	SWP
C1	0.0 / 0.0 / 0.	0.99697 / 5.09 / 1676.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99784 / 91.80 / 42500.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99611 / 21.81 / 5595.	0.0 / 0.0 / 0.	0.0 / 0.01 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B4	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B5	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B6	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99206 / 16.19 / 2022.	RA
C2	0.0 / 0.0 / 0.	0.99697 / 5.09 / 1676.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99784 / 91.80 / 42500.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99611 / 21.81 / 5595.	0.0 / 0.0 / 0.	0.0 / 0.01 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B7	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B8	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
B9	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99598 / 5.38 / 1333.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99785 / 5.78 / 2681.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99108 / 16.16 / 1795.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	
C3	0.0 / 0.0 / 0.	0.99697 / 5.09 / 1676.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99784 / 91.80 / 42500.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.99611 / 21.81 / 5595.	0.0 / 0.0 / 0.	0.0 / 0.01 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	0.0 / 0.0 / 0.	

Exhibit 7 (continued)

TABLE 13

REQUIRED SE ITEMS TO BE PURCHASED

EXPECTED SE UTILIZATION (HRS/8D)

(DETERMINE SEND NUMBER USING KEY GIVEN AT SIDE OF TABLE)

SITE																						
DEPOT			2	2	0	0	2	0	0	0	0			0.7	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0
	10	0	0	0	0	0	0	0	0	0	0	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20	0	2	0	2	0	2	2	2	2	2	20	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.3	0.1	0.6
	30	2	0	2	0	0	0	0	0	0	0	30	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	40	0	2	2	2	2	2	2	2	0	0	40	0.0	0.6	0.3	0.6	0.3	0.6	1.0	0.9	0.0	0.0
	50	2	2	2	0	0	2	2	2	2	2	50	1.0	1.0	0.9	0.0	0.0	0.4	0.6	0.6	0.6	0.9
	60	2	2	2	0	0	0	0	2	2	2	60	0.6	0.0	0.3	0.0	0.0	0.0	0.0	0.7	0.3	0.6
	70	0	0	0	0	0	0	0	0	0	0	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	80	0	2	0	2	0	4	2	0	2	2	80	0.0	0.6	0.0	0.9	0.0	0.4	0.3	0.0	0.9	0.9
	90	2	2	0	2	2	2	0	0	0	0	90	0.6	1.0	0.0	0.6	0.9	0.9	0.0	0.0	0.0	0.0
	100	0	0	0	0	2	2	2	0	0	0	100	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0
	110	0	0	0	0	0	0	0	0	0	0	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	120	0	0	2	2	0	0	0	2	0	0	120	0.0	0.0	0.9	0.3	0.0	0.0	0.0	1.0	0.0	0.0
	130	0	0	0	0	0	0	0	0	0	0	130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	140	0	0	0	2	0	0	0	0	0	0	140	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	150	2	0	0	2	2	2	2	2	2	2	150	0.0	0.0	0.0	0.7	0.7	0.3	0.3	0.3	0.3	0.3
	160	2	2	2	2	2	2	2	0	0	0	160	0.3	0.3	0.7	0.3	0.3	0.3	0.3	0.0	0.0	0.0
	170	2	2									170	0.3	0.3								
A1			0	0	0	0	0	0	0	0	0			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0	0	0	0	0	0	0	0	0	0	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20	0	0	0	0	0	0	0	0	0	0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	30	0	0	0	0	0	0	0	0	0	0	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	40	0	1	1	1	1	1	1	1	0	0	40	0.0	12.4	6.6	12.2	5.8	12.4	16.4	17.7	0.0	0.0
	50	1	1	1	0	0	1	1	1	1	1	50	18.6	18.3	18.4	0.0	0.0	12.2	12.4	12.4	12.2	18.4
	60	1	0	0	0	0	0	0	0	0	1	60	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4
	70	0	0	0	0	0	0	0	0	0	0	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	80	0	1	0	1	0	2	1	0	1	1	80	0.0	12.4	0.0	17.7	0.0	5.2	5.3	0.0	17.7	18.7
	90	1	1	0	1	1	1	0	0	0	0	90	12.4	18.1	0.0	12.2	18.4	18.4	0.0	0.0	0.0	0.0
	100	0	0	0	0	1	1	0	0	0	0	100	0.0	0.0	0.0	0.0	5.3	12.4	0.0	0.0	0.0	0.0
	110	0	0	0	0	0	0	0	0	0	0	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	120	0	0	1	0	0	0	0	1	0	0	120	0.0	0.0	18.4	0.0	0.0	0.0	0.0	18.6	0.0	0.0
	130	0	0	0	0	0	0	0	0	0	0	130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	140	0	0	0	0	0	0	0	0	0	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	150	0	0	0	1	1	1	1	1	0	0	150	0.0	0.0	0.0	13.1	14.0	5.3	5.3	5.3	0.0	0.0
	160	0	1	1	1	1	1	1	0	0	0	160	0.0	5.3	13.1	5.6	5.6	5.6	5.6	0.0	0.0	0.0
	170	0	0									170	0.0	0.0								
A2			0	0	0	0	0	0	0	0	0			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0	0	0	0	0	0	0	0	0	0	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20	0	0	0	0	0	0	0	0	0	0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	30	0	0	0	0	0	0	0	0	0	0	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	40	0	1	1	1	1	1	1	1	0	0	40	0.0	12.2	6.6	12.2	5.6	12.2	16.7	17.0	0.0	0.0
	50	1	1	1	0	0	1	1	1	1	1	50	18.7	18.5	17.6	0.0	0.0	12.2	12.2	12.2	12.2	17.6
	60	1	0	0	0	0	0	0	0	0	1	60	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2
	70	0	0	0	0	0	0	0	0	0	0	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	80	0	1	0	1	0	2	1	0	1	1	80	0.0	12.2	0.0	17.0	0.0	5.6	4.6	0.0	17.0	17.9
	90	1	1	0	1	1	1	0	0	0	0	90	12.2	18.5	0.0	12.2	17.6	17.6	0.0	0.0	0.0	0.0
	100	0	0	0	0	1	1	0	0	0	0	100	0.0	0.0	0.0	0.0	4.8	12.2	0.0	0.0	0.0	0.0
	110	0	0	0	0	0	0	0	0	0	0	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	120	0	0	1	0	0	0	0	1	0	0	120	0.0	0.0	17.6	0.0	0.0	0.0	0.0	17.8	0.0	0.0
	130	0	0	0	0	0	0	0	0	0	0	130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	140	0	0	0	0	0	0	0	0	0	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	150	0	0	0	1	1	1	1	1	0	0	150	0.0	0.0	0.0	12.9	13.8	4.6	4.6	4.8	0.0	0.0
	160	0	1	1	1	1	1	1	0	0	0	160	0.0	4.8	12.9	5.0	5.0	5.0	5.0	0.0	0.0	0.0
	170	0	0									170	0.0	0.0								

Exhibit 7 (continued)

Table 13 (continued)

A3			0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	0	0
	40	0	1	1	1	1	1	1	1	0	0
	50	1	1	1	0	0	1	1	1	1	1
	60	1	0	0	0	0	0	0	0	0	1
	70	0	0	0	0	0	0	0	0	0	0
	80	0	1	0	1	0	2	1	0	1	1
	90	1	1	0	1	1	1	0	0	0	0
	100	0	0	0	0	1	1	0	0	0	0
	110	0	0	0	0	0	0	0	0	0	0
	120	0	0	1	0	0	0	0	1	0	0
	130	0	0	0	0	0	0	0	0	0	0
	140	0	0	0	0	0	0	0	0	0	0
	150	0	0	0	1	1	1	1	1	0	0
	160	0	1	1	1	1	1	1	0	0	0
	170	0	0								

		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	12.2	6.6	12.2	5.6	12.2	16.7	17.0	0.0	0.0
50	18.7	18.5	17.6	0.0	0.0	12.2	12.2	12.2	12.2	17.6
60	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	12.2	0.0	17.0	0.0	5.6	4.8	0.0	17.0	17.9
90	12.2	18.5	0.0	12.2	17.6	17.6	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	4.8	12.2	0.0	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	17.6	0.0	0.0	0.0	0.0	17.8	0.0	0.0
130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	12.9	13.8	4.8	4.8	4.8	0.0	0.0
160	0.0	4.8	12.9	5.0	5.0	5.0	5.0	0.0	0.0	0.0
170	0.0	0.0								

B1 NO SE FOR THIS SITE

B2 NO SE FOR THIS SITE

B3 NO SE FOR THIS SITE

C1			1	1	0	0	1	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0
	20	0	1	0	1	0	1	1	1	0	0
	30	0	0	0	0	0	0	0	0	0	0
	40	0	1	1	1	1	1	1	1	0	0
	50	1	1	1	0	0	1	1	1	1	1
	60	1	1	1	0	0	0	0	1	1	1
	70	0	0	0	0	0	0	0	0	0	0
	80	0	1	0	1	0	2	1	0	1	1
	90	1	1	0	1	1	1	0	0	0	0
	100	0	0	0	0	1	1	1	0	0	0
	110	0	0	0	0	0	0	0	0	0	0
	120	0	0	1	1	0	0	0	1	0	0
	130	0	0	0	0	0	0	0	0	0	0
	140	0	0	0	1	0	0	0	0	0	0
	150	1	0	0	1	1	1	1	1	1	1
	160	1	1	1	1	1	1	1	0	0	0
	170	1	1								

		13.8	2.9	0.0	0.0	5.4	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	1.0	0.0	13.0	13.0	6.7	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	13.0	4.4	12.0	8.6	13.0	23.4	19.5	0.0	0.0
50	23.4	23.2	20.2	0.0	0.0	12.0	13.0	13.0	12.0	20.2
60	13.0	1.0	5.4	0.0	0.0	0.0	0.0	13.8	5.4	13.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	13.0	0.0	19.5	0.0	5.4	6.5	0.0	19.5	20.5
90	13.0	22.1	0.0	12.0	20.2	20.2	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	6.5	13.0	0.0	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	20.2	6.5	0.0	0.0	0.0	22.4	0.0	0.0
130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
140	0.0	0.0	0.0	23.2	0.0	0.0	0.0	0.0	0.0	0.0
150	1.0	0.0	0.0	13.8	16.7	6.5	6.5	6.5	6.5	6.5
160	6.5	6.5	13.8	6.7	6.7	6.7	6.7	0.0	0.0	0.0
170	4.4	6.5								

B4 NO SE FOR THIS SITE

B5 NO SE FOR THIS SITE

B6 NO SE FOR THIS SITE

Exhibit 7 (continued)

Table 13 (concluded)

C2		1	1	0	0	1	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
20	0	1	0	1	0	1	1	1	0	0
30	0	0	0	0	0	0	0	0	0	0
40	0	1	1	1	1	1	1	1	0	0
50	1	1	1	0	0	1	1	1	1	1
60	1	1	1	0	0	0	0	1	1	1
70	0	0	0	0	0	0	0	0	0	0
80	0	1	0	1	0	2	1	0	1	1
90	1	1	0	1	1	1	0	0	0	0
100	0	0	0	0	1	1	1	0	0	0
110	0	0	0	0	0	0	0	0	0	0
120	0	0	1	1	0	0	0	1	0	0
130	0	0	0	0	0	0	0	0	0	0
140	0	0	0	1	0	0	0	0	0	0
150	1	0	0	1	1	1	1	1	1	1
160	1	1	1	1	1	1	1	0	0	0
170	1	1								

		13.8	2.9	0.0	0.0	5.4	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	1.0	0.0	13.0	13.0	6.7	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	13.0	4.4	12.0	8.6	13.0	23.4	19.5	0.0	0.0
50	23.5	23.2	20.3	0.0	0.0	12.0	13.0	13.0	12.0	20.3
60	13.0	1.0	5.4	0.0	0.0	0.0	0.0	13.8	5.4	13.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	13.0	0.0	19.5	0.0	9.4	6.5	0.0	19.5	20.5
90	13.0	22.2	0.0	12.0	20.3	20.3	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	6.5	13.0	0.8	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	20.3	6.5	0.0	0.0	0.0	22.4	0.0	0.0
130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
140	0.0	0.0	0.0	23.2	0.0	0.0	0.0	0.0	0.0	0.0
150	1.0	0.0	0.0	13.9	16.7	6.5	6.5	6.5	6.5	6.5
160	6.5	6.5	13.8	6.7	6.7	6.7	6.7	0.0	0.0	0.0
170	4.4	6.5								

B7 NO SE FOR THIS SITE

B8 NO SE FOR THIS SITE

B9 NO SE FOR THIS SITE

C3		1	1	0	0	1	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
20	0	1	0	1	0	1	1	1	0	0
30	0	0	0	0	0	0	0	0	0	0
40	0	1	1	1	1	1	1	1	0	0
50	1	1	1	0	0	1	1	1	1	1
60	1	1	1	0	0	0	0	1	1	1
70	0	0	0	0	0	0	0	0	0	0
80	0	1	0	1	0	2	1	0	1	1
90	1	1	0	1	1	1	0	0	0	0
100	0	0	0	0	1	1	1	0	0	0
110	0	0	0	0	0	0	0	0	0	0
120	0	0	1	1	0	0	0	1	0	0
130	0	0	0	0	0	0	0	0	0	0
140	0	0	0	1	0	0	0	0	0	0
150	1	0	0	1	1	1	1	1	1	1
160	1	1	1	1	1	1	1	0	0	0
170	1	1								

		13.8	2.9	0.0	0.0	5.4	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	1.0	0.0	13.0	13.0	6.7	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	13.0	4.4	12.0	8.6	13.0	23.4	19.5	0.0	0.0
50	23.4	23.2	20.2	0.0	0.0	12.0	13.0	13.0	12.0	20.2
60	13.0	1.0	5.4	0.0	0.0	0.0	0.0	13.8	5.4	13.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	13.0	0.0	19.5	0.0	9.4	6.5	0.0	19.5	20.5
90	13.0	22.1	0.0	12.0	20.2	20.2	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	6.5	13.0	0.8	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	20.2	6.5	0.0	0.0	0.0	22.4	0.0	0.0
130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
140	0.0	0.0	0.0	23.2	0.0	0.0	0.0	0.0	0.0	0.0
150	1.0	0.0	0.0	13.8	16.7	6.5	6.5	6.5	6.5	6.5
160	6.5	6.5	13.8	6.7	6.7	6.7	6.7	0.0	0.0	0.0
170	4.4	6.5								

TOTAL NUMBER OF SE ITEMS PURCHASED (ALL SITES INCLUDING DEPOT)
DETERMINE SERD NUMBER USING KEY AT SIDE OF TABLE

		5	5	0	0	5	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
20	0	5	0	5	0	5	5	5	2	2
30	2	0	2	0	0	0	0	0	0	0
40	0	8	8	8	8	8	8	8	0	0
50	8	8	8	0	0	8	8	8	8	8
60	8	5	5	0	0	0	0	5	5	8
70	0	0	0	0	0	0	0	0	0	0
80	0	8	0	8	0	16	8	0	8	8
90	8	8	0	8	8	8	0	0	0	0
100	0	0	0	0	8	8	5	0	0	0
110	0	0	0	0	0	0	0	0	0	0
120	0	0	8	5	0	0	0	8	0	0
130	0	0	0	0	0	0	0	0	0	0
140	0	0	0	5	0	0	0	0	0	0
150	5	0	0	8	8	8	8	8	5	5
160	5	8	8	8	8	8	8	0	0	0
170	5	5								

Exhibit 7 (continued)

TABLE 14

REQUIRED MEN TO BE TRAINED
ASSUMING: BASE 140. MAN HRS. AVAILABLE PER MONTH AT 15 BASES
DEPOT 147. MAN HRS. AVAILABLE PER MONTH AT 1 DEPOTS

SITE	MINIMUM NO. MEN TRAINED (USING COMMAND REQUIREMENT)	AF TRAINING TURNOVER RATE	NO. MEN TRAINED (PLANNED)	FRACTION UTILIZATION OF A ONE-MAN SHOP
A1	6	0.25	6	0.177
A2	6	0.25	6	0.169
A3	6	0.25	6	0.169
B1	6	0.25	0	0.0
B2	6	0.25	0	0.0
B3	6	0.25	0	0.0
C1	6	0.25	6	0.221
B4	6	0.25	0	0.0
B5	6	0.25	0	0.0
B6	6	0.25	0	0.0
C2	6	0.25	6	0.221
B7	6	0.25	0	0.0
B8	6	0.25	0	0.0
B9	6	0.25	0	0.0
C3	6	0.25	6	0.221
DEPOT	15	0.15	15	0.007

Exhibit 7 (continued)

TABLE 15

SYSTEMS COST

TOTAL LIFE CYCLE COST=$ 26.294 MILLION
ACQUISITION COST=$ 16.569 MILLION 64. %
SUPPORT COST=$ 9.725 MILLION 36. %

COST ELEMENT	1	2	3	4	5	6	7	8	9	10	11
COST	13414184.	2447397.	0.	448322.	5128936.	78683.	2579537.	166847.	1621834.	276175.	132492.
%	51.015	9.308	0.0	1.705	19.506	0.299	9.810	0.635	6.168	1.050	0.504

COST ELEMENTS	ACQUISITION (% USED IN ACQUISITION CALCULATION)
1 HARDWARE ACQUISITION	100.
2 SPARES ACQUISITION	100.
3 MBS: ACQ & SUPPORT	0.
4 OFF-EQUIPMENT REPAIRS	0.
5 REPLACEMENT LRUS AND SRUS	10.
6 ON- EQUIPMENT REPAIRS	0.
7 SUPPORT EQUIPMENT (SE)	0.
8 INITIAL TRAINING	100.
9 RECURRING TRAINING	0.
10 NEW ITEM INVENTORY MANAGEMENT	10.
11 TECHNICAL DATA	0.

Exhibit 7 (continued)

TABLE 16

TERMINAL COSTS - RANKED BY LCC

TOTAL LIFE CYCLE COST=$ 26.294 BILLION

COST ELEMENT TERM(K)	1	2	3	4	5	6	7	LCC/TERM	O&S	TOTAL	PCT	QUAN.
14A	6604620.	794560.	0.	17441.	299474.	11868.	0.	643997.	298836.	7727960.	29.4	12
RC5	1356408.	395660.	0.	49389.	1277622.	16648.	0.	171985.	1215895.	3095725.	11.8	78
2	1610524.	346496.	0.	30577.	853707.	15635.	0.	86574.	814548.	2856937.	10.9	33
1A	914057.	247970.	0.	35422.	986667.	8721.	0.	121824.	932143.	2192835.	8.3	18
B52	830535.	226753.	0.	21247.	522601.	7317.	0.	107230.	498904.	1608450.	6.1	15
P5A	498321.	136052.	0.	22281.	548050.	6884.	0.	134621.	522410.	1211588.	4.6	9
2B	550772.	159110.	0.	18029.	452060.	7369.	0.	65963.	432251.	1187339.	4.5	18
9	407628.	54484.	0.	3580.	53526.	1292.	0.	86751.	53045.	520509.	2.0	6
13	287745.	37035.	0.	1322.	23550.	717.	0.	350369.	23233.	350369.	1.3	1
8A	224612.	18925.	0.	1697.	23106.	809.	0.	269148.	23301.	269148.	1.0	1
WCP	120300.	27103.	0.	3518.	85350.	1339.	0.	79203.	81672.	237610.	0.9	3
SWP	8662.	3248.	0.	162.	3223.	84.	0.	15379.	3147.	15379.	0.1	1
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
TAC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
LCC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
5D	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
ATC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
C-1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
C-3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
C-9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
E-1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
E-3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
E-12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
P-2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
P-8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0
P-11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0

NOTE: COST ELEMENTS 8-11 ALLOCATED ONLY TO SYSTEM COSTS.

Exhibit 7 (continued)

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

TABLE 17

LRU COSTS - RANKED BY LCC

LRU/EQU	1	2	3	4	5	6	7	8	LCC/FAIL	DDS	TOTAL	FAILS
11	1978713.	679558.	0.	168843.	1640988.	22957.	0.	7394.	2419.	1668688.	4498451.	1859.
23	1610611.	381005.	0.	104850.	1608702.	11177.	0.	7394.	2034.	1563858.	3723737.	1830.
12	2320448.	240639.	0.	21770.	148192.	2806.	0.	6162.	13748.	157948.	2740014.	199.
19	1460256.	379667.	0.	13074.	113261.	1525.	0.	7394.	19182.	116534.	1975174.	103.
16	987464.	191447.	0.	52443.	593605.	12605.	0.	2465.	1900.	599292.	1640025.	968.
18	953496.	157046.	0.	23502.	84171.	2922.	0.	3697.	5626.	102178.	1224832.	218.
9	688839.	146117.	0.	11243.	327603.	9901.	0.	7394.	3359.	315987.	1191096.	355.
3	1136031.	0.	0.	1327.	1156.	71.	0.	0.	276258.	2438.	1138564.	4.
2	1080668.	0.	0.	68.	98.	6102.	0.	0.	4051101.	6258.	1086934.	0.
20	310288.	99292.	0.	25138.	240623.	4555.	0.	3697.	1465.	246254.	683593.	466.
17	210489.	46775.	0.	12293.	305443.	1618.	0.	6162.	2200.	288809.	582780.	265.
21	277178.	103982.	0.	2850.	34851.	910.	0.	3697.	7927.	35126.	423429.	53.
22	119654.	18696.	0.	3572.	20480.	624.	0.	1232.	1603.	22628.	164258.	102.
1	123827.	0.	0.	14.	28.	3.	0.	0.	1264204.	42.	123872.	0.
5	79224.	3212.	0.	6889.	3629.	820.	0.	1232.	2273.	10975.	95005.	42.
4	38704.	0.	0.	81.	5496.	38.	0.	0.	31209.	5066.	44319.	1.
6	19672.	0.	0.	357.	209.	41.	0.	1232.	10123.	586.	21512.	2.
8	17311.	0.	0.	6.	386.	5.	0.	0.	88349.	359.	17708.	0.
10	0.	0.	0.	0.	0.	0.	0.	6162.	0.	0.	6162.	0.
7	1313.	0.	0.	2.	13.	4.	0.	0.	10171.	17.	1332.	0.
13	0.	0.	0.	0.	0.	0.	0.	1023.	0.	0.	1023.	0.
14	0.	0.	0.	0.	0.	0.	0.	511.	0.	0.	511.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

NOTE: COST ELEMENTS 9-11 NOT ALLOCATED TO INDIVIDUAL LRUS

Exhibit 7 (continued)

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

TABLE 19

LRU COST - UNRANKED

TOTAL LIFE CYCLE COST=$ 26.294 MILLION

LRU/EQU	1	2	3	4	5	6	7	8	LCC/FAIL	DSS	TOTAL	FAILS
1	123827.	0.	0.	14.	28.	3.	0.	0.	1264204.	42.	123872.	0.
2	1080668.	0.	0.	68.	98.	6102.	0.	0.	4051101.	6258.	1086934.	0.
3	1136031.	0.	0.	1327.	1156.	71.	0.	0.	276258.	2438.	1138584.	4.
4	38704.	0.	0.	81.	5496.	38.	0.	0.	31209.	5066.	44319.	1.
5	79224.	3212.	0.	6889.	3629.	820.	0.	1232.	2279.	10975.	95005.	42.
6	19672.	0.	0.	357.	209.	41.	0.	1232.	10121.	586.	21512.	2.
7	1313.	0.	0.	2.	13.	4.	0.	0.	10171.	17.	1332.	0.
8	17311.	0.	0.	6.	386.	5.	0.	0.	88349.	359.	17708.	0.
9	688839.	146117.	0.	11243.	327603.	9901.	0.	7394.	3359.	315987.	1191096.	355.
10	0.	0.	0.	0.	0.	0.	0.	6162.	0.	0.	6162.	0.
11	1978713.	679558.	0.	168843.	1640988.	22957.	0.	7394.	2419.	1668688.	4498451.	1859.
12	2320448.	240639.	0.	21770.	148192.	2806.	0.	6162.	13748.	157948.	2740014.	199.
13	0.	0.	0.	0.	0.	0.	0.	1023.	0.	0.	1023.	0.
14	0.	0.	0.	0.	0.	0.	0.	511.	0.	0.	511.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	987464.	191447.	0.	52443.	593605.	12605.	0.	2465.	1900.	599292.	1840025.	968.
17	210489.	46775.	0.	12293.	305443.	1618.	0.	6162.	2200.	288809.	582780.	265.
18	953496.	157046.	0.	23502.	84171.	2922.	0.	3697.	5626.	102178.	1224832.	218.
19	1460256.	379667.	0.	13074.	113261.	1525.	0.	7394.	19182.	116534.	1975174.	103.
20	310288.	99292.	0.	25138.	240623.	4555.	0.	3697.	1465.	246254.	683593.	466.
21	277178.	103942.	0.	2850.	34851.	910.	0.	3697.	7927.	35126.	423429.	53.
22	119654.	18696.	0.	3572.	20480.	624.	0.	1232.	1608.	22628.	164258.	102.
23	1610611.	381005.	0.	104850.	1608702.	11177.	0.	7394.	2034.	1563858.	3723737.	1830.

Exhibit 7 (concluded)

APPENDIX B

QUANTITIES OF LRUs

The quantity of LRUs of a given type I which are installed in all of the terminals at all of the bases of the AFSATCOM system configuration is

$$QLRU1(I) = \sum_{K} QPA(I,K)*NTS(K)$$

where QPA(I,K) is the quantity of LRUs of type I installed in a terminal of type K, and NTS(K) is the total number of terminals of type K to be purchased. Equivalently, one could define

$$QLB1(I,NS) = \sum_{K} QPA(I,K)*IT(K,NS)$$

as the quantity of LRUs of type I which are installed in all of the terminals at base NS; then

$$QLRU1(I) = \sum_{NS} QLB1(I,NS)$$

since

$$\sum_{NS} IT(K,NS) = NTS(K)$$

as noted in the discussion of Cost Element 1, above.

The quantity of LRUs of type I which are acquired for initial sparing for AFSATCOM is

$$QLRU2(I) = \sum_{NS} SB(I,NS) + SD(I)$$

where SB(I,NS) and SD(I) are the number of spares of LRU type I to be acquired for inventory at base NS and at the depot, respectively.

The quantity of LRUs of type I which are installed in all of the maintenance bench sets at all of the bases of the AFSATCOM system configuration which have such bench sets is

$$QLRU3(I) = \sum_{NS} HMU(NHM(NS),I)$$

where HMU(NHM,I) is the quantity of LRUs of type I installed in maintenance bench set type NHM, and NHM(NS) is the type of maintenance bench set used at base NS. If no maintenance bench set exists at base NS, then NHM(NS)=0.

The above quantities play a role in prorating to terminals those cost elements which are aggregated by LRU type only. For example, that portion of Cost Element 2 attributable to LRU type I, found as in the equation for *SC(2)* but with the summation on I omitted, is multiplied by

$$QPA(I,K)*NTS(K)/QLRU1(I)$$

for proration to terminal type K.

In test runs of the AFSATCOM LCC Model, it is desirable to employ subsets of the full AFSATCOM system configuration for economy of computer time and storage. Similarly, subsets of the full AFSATCOM system configuration may be the focus of special logistics cost studies. By virtue of the LRU quantities defined above, the user of the model need not worry about consistency between the data files of the matrix [QPA(I,K)], of the matrix [IT(K,NS)], and of the master list of LRU data and terminal data. Thus, for example, if LRU type I appears in the master list of LRU data, but in a given run of the AFSATCOM LCC Model the only use of that LRU type is in a terminal which itself is not used at any base, a test for QLRU1(I)=0 will cause certain computations to be withheld, and will preclude the prorating of LCC cost elements to that LRU type.

APPENDIX C

TERMINAL MEAN DOWN TIME BY LRU TYPE

The mean down time for a particular terminal of type K at base NS, given a failure of an LRU of type I in that terminal, which is the expression denoted by MDTLRU(I,K,NS) in the text, is derived via the network portrayal of LRU repair/replacement pipeline presented in Exhibit 8. This network is developed from left to right by tracing the alternative paths/outcomes which may be taken by the failed LRU. Probabilities are entered onto the path in parentheses, followed by an entry of the time required for that path.

A "generalized pipeline" time average is then developed by working from right to left through the network, as follows:

(i) Probabilities and time entries on branches emanating from a common node are multiplied together;

(ii) these probability-time products are added together;

(iii) this sum, representing the average pipeline time among branches emanating from a common node, is placed on the incoming branch to the left of that node as an additional time entry;

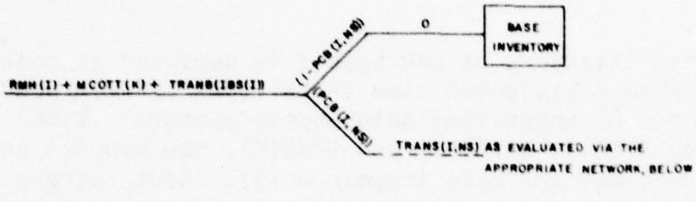
(iv) multiple time entries on the same branch are added together.

This process is repeated node by node through the network until a single time entry exists on the leftmost branch; this final time entry is the generalized pipeline average for the network, namely, the mean down time for a particular terminal of type K at base NS, given a failure of LRU type I.

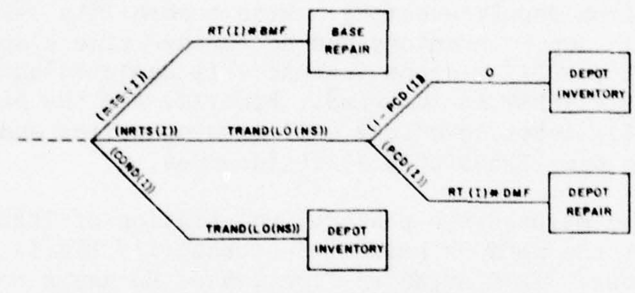
The network of Exhibit 8 is developed via the following sequence of actions for LRU type I in terminal type K at base NS: To start with, remove and replace time RMH(I), mean checkout time MCOTT(K), and on-base transportation time TRANB(IBS(I)) must elapse regardless of subsequent outcome. With probability 1-PCB(I,NS), a spare LRU exists in base inventory and no further time elapses. But with probability PCB(I,NS), base inventory is depleted and the mean replacement time TRANS(I,NS) is incurred.

Given that inventory of LRU type I is depleted at base NS, the network for mean replacement time TRANS(I,NS) is developed as follows under non-centralized maintenance posture: With probabilities RTS(I), NRTS(I), and COND(I), the sources sought for the replacement LRU are base (repair only), depot (either inventory or repair), and depot (inventory only), respectively. On the network branch to which probability RTS(I) is attributed, the base repair time RT(I)*BMF is incurred. The branch with the NRTS(I) probability must incur the transportation time TRAND(LO(NS)) for shipment of a replacment LRU from the depot to the base; further branching now describes the actions taken according to whether the LRU is available from depot inventory. With probability 1-PCD(I), a spare LRU exists in depot inventory and no further time elapses. But with probability PCD(I), depot inventory is depleted and the base repair time RT(I)*DMF is incurred. Finally, for the branch of probability COND(I), depot inventory will always suffice and only the transportation time TRAND(LO(NS)) is incurred.

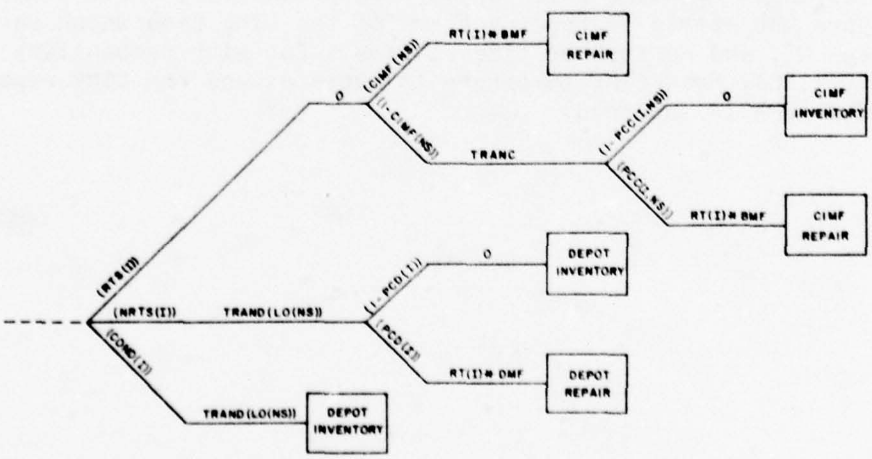
For centralized maintenance posture, calculation of TRANS(I,NS) requires only that the network branch of probability RTS(I) be modified, as follows: If CIMF(NS)=1 (*i.e.*, base NS has a repair facility), then CIMF repair time RT(I)*BMF is incurred. (Recall that base NS inventory is depleted, by definition of TRANS(I,NS).) Otherwise CIMF(NS)=0, hence 1-CIMF(NS)=1, and the corresponding branch must incur the transportation time TRANC for shipment of a replacement LRU from the CIMF for that base; further branching now describes the actions taken according to whether the LRU is available from CIMF inventory. With probability 1-PCC(I,NS), a spare LRU exists in the inventory of the CIMF base which services base NS, and no further time elapses. But with probability PCC(I,NS), this CIMF inventory is depleted and the CIMF repair time RT(I)*BMF is incurred.



(A) NETWORK FOR MEAN DOWN TIME FOR LRU TYPE I



(B) EVALUATION OF MEAN REPLACEMENT TIME TRANS(I,NS) FOR "NON-CENTRALIZED" MAINTENANCE POSTURE



(C) EVALUATION OF MEAN REPLACEMENT TIME TRANS(I,NS) FOR "CENTRALIZED" MAINTENANCE POSTURE

10-47,785

EXHIBIT 8. NETWORK PORTRAYAL OF REPAIR/REPLACEMENT PIPELINE FOR FAILED LRU OF TYPE I, IN TERMINAL TYPE K AT BASE NS

GLOSSARY

We list below the definitions of (1) all capital-letter abbreviations, acronyms, and subroutine names, and (2) all FORTRAN variable names, indices, and function names used in this document. The Glossary presents the following additional information after the descriptive definition of a FORTRAN variable name: {units} (responsible authority or source of numerical data for input variables, reference to appropriate section of text for variables computed internally)/subroutine or Life Cycle Cost subcost(s) in which the defined variable appears, either directly or indirectly.

<u>Abbreviations, Acronyms, Subroutine Names</u>

AF	Air Force.
AFLC	Air Force Logistics Command.
AFSATCOM	Air Force Satellite Communications System.
AVAIL	Abbreviation for the Availability Routine, a subset of the LCC Routine.
BITE	Built-in test equipment.
CIMF	Centralized intermediate maintenance facility, the designation of the one base with repair facility in each grouping of bases, when using the "centralized" maintenance posture.
CONSO	A subroutine of the LCC Routine, the vehicle by which the "centralized" maintenance posture is implemented.
EBOS	The Expected Back-Order Sparing Subroutine.
LCC	Life cycle cost, also the Life Cycle Cost Routine.
LRU	Line replaceable unit; for AFSATCOM, equipment which is replaceable by organizational-level personnel at the terminals.
LSC	Logistics support cost; in particular, the Logistics Support Cost Model developed by AFLC (see Reference [1]), a predecessor to the AFSATCOM LCC Model developed by The MITRE Corporation.

MBS	Maintenance bench set(s).
MDT	Mean down time. MDT differs from MTTR, mean time to repair, in that MDT is a measure of elapsed calendar time, including time spent awaiting parts on order, whereas MTTR is a measure of actual repair time only.
MTBD	Mean time between demands. MTBD differs from MTBF, mean time between failures, in that MTBD is a measure of elapsed calendar time, including times during which the equipment is not operating, if any, whereas MTBF is a measure of actual equipment operating time only.
MTBF	Mean time between failures. (Refer to definition of MTBD, above.)
MTTR	Mean time to repair. (Refer to definition of MDT, above.)
NORS	Not operationally ready due to supply, the status designator of an AFSATCOM terminal which is down awaiting arrival of a component which is not available from base inventory.
ORLA	Any optimum repair-level analysis (see, e.g., Reference [3]).
SC	Subcost, i.e., a cost element of LCC. E.g., SC(7) implies Cost Element 7.
SE	Support Equipment (formerly: Aerospace Ground Equipment).
SERD	Support Equipment Review Document (formerly: Aerospace Ground Equipment Review Document).
SITELCC	The name of the FORTRAN program for the AFSATCOM LCC Model developed by The MITRE Corporation.
SITEORLA	The name of a site-specific ORLA Routine developed at The MITRE Corporation, extending upon the 1974 work of J. J. Fabish (Reference [4]), then of Sacramento ALC/MMER, to support AFSATCOM life cycle cost analyses.

SRU	Shop replaceable unit; for AFSATCOM, the components within an LRU which are replaceable at a repair shop but not at the terminals.
WBS	Work Breakdown Structure.
WUC	Work unit code.

FORTRAN Variable Names, Indices, Function Names

A(I,L)

LRU-SE usage or cross-reference indicator; A(I,L)=1 if SE (support equipment) of SERD (Support Equipment Review Document) item number L is used to isolate failed SRUs in an LRU of type I, A(I,L)=0 otherwise. {0 or 1 indicator} (Contractor; assignment of SE items to LRU types is controllable by the user of the model via this matrix.)/LCC SC(7)

AB(I,NS)

"Load factor" for computing inventory size and probability of backordering, for LRU type I at base NS. See Glossary entry for AS, for further definition. {items} (Computed internally; see discussion of Sparing Routine inputs.)/EBOS calling procedure for LCC SC(2) and for AVAIL

ACPP

Acquisition cost per page of technical data. {$/page} (Contractor)/LCC SC(11)

AD(I)

"Load factor" for computing inventory size and probability of backordering, for LRU type I at the depot. See Glossary entry for AS, for further definition. {items} (Computed internally; see discussion of Sparing Routine inputs.)/EBOS calling procedure for LCC SC(2) and for AVAIL

AMA(L)

Average annual portion of the fraction of acquisition cost of SE item L which is added on to represent maintenance (including labor and parts) costs of that SE item over the life cycle. {decimal fraction/yr.} (Contractor)/LCC SC(7)

AMAH

Average annual portion of the fraction of acquisition cost of a maintenance bench set which is added on to represent maintenance (including labor and parts) costs of the maintenance bench set itself. {decimal fraction/yr.} (AF; selected from the file of AMA(L) for a predetermined value of L)/LCC SC(3)

AS

Input variable for Subroutine EBOS: "Load factor." For a given situation of interest (LRUs of type I, at base NS or at depot) the load factor is the LRU failure rate (per month) multiplied by the average pipeline time (in months), hence is the average number of LRUs in the pipeline. {items} (Receives value of either AB(I,NS) or AD(I) from the EBOS calling procedure of the LCC Routine; see discussion of Sparing Routine inputs, including Exhibit 4.)/EBOS

ASEC(I)

Average SRU exchange cost per maintenance action resulting from failure of an LRU of type I. This average is comprised of the failure-rate-weighted costs of the SRUs in the LRU, using repair cost (including cost of labor, materials, SE, spares, packing and shipping, etc.) for repairable SRUs, replacement costs for disposable SRUs. In the case where LRU type I does not further subdivide into SRUs then ASEC(I) is set equal to RM(I), the average repair materials cost per failure of LRU type I. {$/item} (Computed by an auxiliary program using results from an ORLA Routine [3] run at the SRU level, with further input from SITEORLA; see Cost Element 5.)/LCC SC(5)

ATOH(K,NS)

Average total operating hours per month of a terminal of type K at base NS. {hrs./mo.} (AF; utilization of terminals at bases is controllable by the user of the model via this matrix.)/LCC SC(4), SC(5), SC(6), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2); AVAIL

AV(K,NS)

Availability of a given terminal of type K at base NS. {decimal fraction} (Computed internally by the Availability Routine.)/AVAIL

AX

Input variable for Subroutine EBOS: Preassigned upper limit on the Sparing Routine output variable EBO, expected number of backorders at a random point in time or per month. {items or items/mo.} (Receives value from a variable named EBO in the EBOS calling procedure of the LCC Routine; see discussion of Sparing Routine inputs, including Exhibit 4.)/EBOS

BAA

Total available active work time, per month, in a base repair shop. {hrs./mo.} (AF)/LCC SC(7), SC(8), SC(9)

BLR

Average base level labor rate. {$/man-hr.} (AF)/LCC SC(4), SC(6)

BMF

Base repair maintenance factor, to be applied to RT(I) to include time to get test equipment, parts, etc. {decimal factor} (Contractor provided this factor for AFSATCOM; Air Force provides this factor in general.)/LCC SC(4), SC(7), SC(8), SC(9); EBOS calling procedure; AVAIL

BRCT

Average base repair cycle time. {mo.}(AF)/EBOS calling procedure for LCC SC(2) and for AVAIL

CA(L)

The unit price of SE item L. Typically, the actual price is dependent upon the total quantity of SE item L to be purchased, NAPH(L). The model currently allows for as many as four price categories, defined by user implementation of as many as three price breakpoints; provision for additional price breakpoints could easily be incorporated. {$/item} (Contractor; a function of NAPH(L))/LCC SC(7)

CIMF(NS)

Indicator function when using centralized maintenance posture; CIMF(NS)=1 if base NS is a centralized intermediate maintenance facility (CIMF) or a stand-alone base among centralized maintenance posture groupings; CIMF(NS)=0 if base NS is a member of a group of bases but not the CIMF for that group. Equivalently, CIMF(NS)=0 if base NS sends equipment to a CIMF elsewhere. {zero or one} (Established by Subroutine CONSO via user´s input vector CONSOL(NS).)/CONSO; LCC SC(4), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

CON

Control variable for maintenance posture. Setting CON=0 causes the model to run in "non-centralized" maintenance posture. Setting CON=1 causes Subroutine CONSO to be called, and the model to run in "centralized" maintenance posture. {zero or one} (User´s control)/CONSO calling procedure

COND(I)

Fraction of removals of LRU of type I expected to be condemned upon failure. {decimal fraction} (Based upon the results of an ORLA Routine [3]; see also Exhibit 3.)/LCC SC(4), SC(5), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

COND(J)

Fraction of removals of SRU of type J expected to be condemned upon failure. {decimal fraction} (Based upon the results of an ORLA Routine [3] run at the SRU level.)/LCC SC(5)

CONSOL(NS)

Vector of designators of bases arranged into groupings for a specific configuration to be implemented by the user under centralized maintenance posture. The base designators are two-character alphanumeric symbols, e.g., 'AB', 'CD', etc. Each grouping of bases is delimited by the double-zero symbol '00'. The first such string indentifies the stand-alone bases (i.e., bases not assigned to any group). Each successive string identifies a grouping of bases, the last of which is the centralized intermediate maintenance facility (CIMF) for that grouping. See example in Exhibit 5. {two-character alphanumeric symbols} (AF; configuration into stand-alone bases, groupings, and CIMFs is controllable by the user via this vector.)/CONSO; LCC SC(4), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

CPA(I)

The number of new "P"-coded assemblies (SRUs) added to the Air Force inventory system, as a result of AFSATCOM acquisition, to support repair of LRUs of type I. {items} (Computed internally; see Cost Element 10.)/LCC SC(10)

CPFB(J)

Cost per failure of SRU type J, given that this SRU type is designated for base repair. {$/item} (Computed by the SITEORLA Routine.)/LCC SC(5)

CPFD(J)

Cost per failure of SRU type J, given that this SRU type is designated for depot repair. {$/item} (Computed by the SITEORLA Routine.)/LCC SC(5)

CPFS(J)

Cost per failure of SRU type J, given that this SRU type is designated for discard upon failure. {$/item} (Computed by the SITEORLA Routine.)/LCC SC(5)

CRCT

Average one-way shipping time from a base (not a CIMF) to the CIMF for that base, when using centralized maintenance posture. {mo.}(AF)/EBOS calling procedure for LCC SC(2) and for AVAIL

DAA

Total available active work time, per month, in a depot repair shop. {hrs./mo.} (AF)/LCC SC(7), SC(8), SC(9)

DFC(A,B,R)

Continuous discount factor function, which evaluates the continuously discounted sum of a series of payments of $1 beginning at time A and ending at time B, for interest rate R. {same units of time as A and B}/LCC SC(4), SC(5), SC(6), SC(7), SC(9), SC(10), SC(11)

```
DFC(A,B,R) =  B - A                              if  R = 0
           =  [EXP(-A*R) - EXP(-B*R)]/R          if  R > 0
```

DLR

Average depot level labor rate. {$/man-hr.} (AF)/LCC SC(4)

DMF

Depot repair maintenance factor, to be applied to RT(I) to include time to get test equipment, parts, etc. {decimal factor} (Contractor provided this factor for AFSATCOM; Air Force provides this factor in general.)/LCC SC(4), SC(7), SC(8), SC(9); AVAIL

DRCT

Average one-way shipping time plus handling and repair time at the depot for all LRU types which undergo depot repair. {mo.} (AF)/EBOS calling procedure for LCC SC(2)

EBO

SITELCC input variable: Preassigned upper limit on expected number of backorders per month for any LRU type at any base or at the depot. {items/mo.} (AFLC guidance; controllable by the user of the model to achieve tradeoff between cost of LRU inventories and availability of terminals.)/EBOS calling procedure for LCC SC(2) and for AVAIL

EBO

Output variable for Subroutine EBOS: Expected number of backorders, at a random point in time or per month, for a given situation of interest (LRUs of type I, at base NS or at the depot). {items or items/mo.} (Computed internally; see discussion of Sparing Routine outputs, including Exhibit 4.)/EBOS

ERHAB(L,NS)

Expected utilization, per month, of SE item (items) of SERD item number L, at a repair shop at base NS. {man-hrs./mo.} (Computed internally; see Cost Element 7.)/LCC SC(7)

ERHAD(L)

Expected utilization, per month, of SE item (items) of SERD item number L, at the depot repair shop. {man-hrs./mo.} (Computed internally; see Cost Element 7.)/LCC SC(7)

ERHB(I,K,NS)

Expected number of repair hours, per month, that LRUs of type I operating in terminals of type K will require at a repair shop at base NS. {man-hrs./mo.} (Computed internally; see Cost Element 7.)/LCC SC(7)

ERHD(I,K)

Expected number of repair hours, per month, that LRUs of type I operating in terminals of type K will require at the depot repair shop. {man-hrs./mo.} (Computed internally; see Cost Element 7.)/LCC SC(7)

ERMH(I,K,NS)

Expected number of hours of organizational-level labor, per month, required to remove and replace LRUs of type I operating in terminals of type K at base NS. {man-hrs./mo.} (Computed internally; see discussion of Cost Element 7 for centralized maintenance posture.)/LCC output only

ERPSB(NS)

Expected repair time required, per month, at base NS. {man-hrs./mo.} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

ERPSD

Expected repair time required, per month, at the depot. {man-hrs./mo.} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

EXF

Input variable for Subroutine EBOS: "Expediting factor". This is the factor by which pipeline time is divided whenever inventory is depleted. If expediting is to be utilized with the Sparing Routine, EXF input must be greater than one. Otherwise, input EXF=1. {numerical factor, greater than or equal to one} (Receives value from the EBOS calling procedure of the LCC Routine; see discussion of Sparing Routine inputs, including Exhibit 4.)/EBOS

EXF(I,NS)

Expediting factor by which pipeline time is divided whenever inventory of LRU type I is depleted at base NS. {numerical factor, greater than or equal to one} (Computed internally; see discussion of Sparing Routine inputs.)/EBOS calling procedure for AVAIL

FAIL(I,K,NS)

Expected number of removals per month of LRU type I in terminal type K at base NS. {items/mo.} (Computed internally; see Cost Element 4.)/LCC SC(4), SC(5), SC(6), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

FAILC(I,K,NS)

Composite expected number of removals per month of LRU type I in terminal type K among shipments from bases without repair facilities to a given CIMF base NS, when using centralized maintenance posture. If base NS is a stand-alone base, i.e., a CIMF servicing only itself, then FAILC(I,K,NS)=0. If base NS does not have a maintenance facility, then FAILC(I,K,NS) is not defined. {items/mo.} (Computed internally; see general discussion for centralized maintenance posture.)/LCC SC(4), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

HMU(NHM,I)

The quantity of LRUs of type I installed in maintenance bench set type NHM. If NHM=0, then HMU(NHM,I)=0 for all LRU types I. {items} (AF; configuration of LRUs in maintenance bench sets is controllable by the user via this matrix.)/LCC SC(3)

HPF(I)

Expected manpower cost to repair an LRU of type I. {$/item} (Computed internally; see Cost Element 4.)/LCC SC(4)

I

Index representing LRU type. {index}/LCC; EBOS calling procedure; AVAIL

IBS(I)

Index corresponding to the location of base supply point (both inventory storage and receipt of incoming shipments) for LRU type I. {index} (AF)/EBOS calling procedure; AVAIL

IBS(I) = 1 if base supply point for LRU type I is located at the line (in vicinity of the terminal(s))

= 2 if base supply point for LRU type I is located at the repair shop (at a distance from the terminal(s))

ICS(NS)

Pointer for base indices NS, which in conjunction with the indicator function CIMF(NS) carries the information of the configuration vector CONSOL(NS) as provided by the user to designate the stand-alone bases, the groupings, and the CIMF base for each grouping, under centralized maintenance posture. {index} (See discussion of Subroutine CONSO.)/CONSO; LCC SC(4), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

IMC

Annual inventory management cost incurred due to introduction of a new "P"-coded item. {$/item/yr.} (AF)/LCC SC(10)

IMH(I)

Average number of man-hours required to repair an LRU of type I in place (i.e., without its removal from the terminal), assuming that such a maintenance action is required. {man-hrs./item} (Contractor)/LCC SC(6)

IT(K,NS)

The number of terminals of type K to be operated at base NS. {items} (AF; configuration of terminals on bases is controllable by the user via this matrix.)/LCC SC(1), SC(4), SC(5), SC(6), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2)

J

Index representing SRU type. {index}/LCC SC(5)

K

Index representing terminal type. {index}/LCC; EBOS calling procedure; AVAIL

KB

Factor to account for increased damage due to handling, and maintenance damage, at the base. {decimal factor} (Contractor & AF)/LCC SC(4), SC(5), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

KC

Factor to account for increased damage due to handling, and maintenance damage, at the CIMF, when using centralized maintenance posture. {decimal factor} (Contractor & AF)/LCC SC(4), SC(5), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

KD

Factor to account for increased damage due to handling, and maintenance damage, at the depot. {decimal factor} (Contractor & AF)/LCC SC(4), SC(5), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

L

Index representing the SERD (Support Equipment Review Document) item number, for SE (support equipment). {index}/LCC

LE(K)

Index corresponding to the environment of terminal type K. {index} (Contractor & AF)/LCC; EBOS calling procedure; AVAIL

LE(K) = 1 if terminal K is Ground Fixed

= 2 if terminal K is Ground Transportable

= 3 if terminal K is Airborne

LO(NS)

Index corresponding to the location of base NS. {index} (AF)/LCC SC(4); EBOS calling procedure; AVAIL

LO(NS) = 1 if base NS is in continental U.S.

= 2 if base NS is overseas, Hawaii, or Alaska

M

Index representing the category number in the grouping of LRU types into categories for training purposes. {index}/LCC SC(8)

MCOTT(K)

Mean checkout time for a terminal of type K. {hrs./item} (AF)/AVAIL

MDT(K,NS)

Mean down time for a given terminal of type K at base NS. See also the definitions of MDT, MTTR, in the list of abbreviations. {hrs.} (Computed internally by the Availability Routine.)/AVAIL

MDTLRU(I,K,NS)

Mean down time for a particular terminal of type K at base NS, given a failure of an LRU of type I in that terminal. {hrs.} (Computed internally by the Availability Routine; see also Appendix C.)/AVAIL

MFAC(LE)

Reliability factor which converts predicted failure rates (reciprocal of mean time between failures) to operational failure rates, based on experience, expected reliability growth, etc., as a function of environment LE. {decimal factor} (Contractor & AF)/LCC SC(4), SC(5), SC(6), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2); AVAIL

MMTB(NS)

The minimum number of men planned for initial training to support AFSATCOM at base NS. {men} (AF)/LCC SC(8), SC(9)

MMTD

The minimum number of men planned for initial training to support AFSATCOM at the depot. {men} (AF)/LCC SC(8), SC(9)

MOTBMA(I,LE)

Predicted mean operating time between maintenance actions, over the life cycle, for an LRU of type I operating in environment LE. {hrs./item} (Contractor)/LCC SC(4), SC(5), SC(6), SC(7), SC(8), SC(9); *EBOS calling procedure for LCC SC(2)*; AVAIL

MOTBMA(J,1)

Predicted mean operating time between maintenance actions, over the life cycle, for an SRU of type J operating in environment LE=1, Ground Fixed. {hrs./item} (Contractor)/LCC SC(5)

MTBDT(K,NS)

Mean time between demands for a given terminal of type K at base NS. See also the definitions of MTBD, MTBF, in the list of abbreviations. {hrs.} (Computed internally by the Availability Routine.)/AVAIL

MTBFT(K)

Mean time between failures for a representative terminal of type K. See also the definitions of MTBD, MTBF, in the list of abbreviations. {hrs.} (Computed internally by the Availability Routine.)/AVAIL

NAPB(L,NS)

The number of SE items of SERD item number L to be purchased for base NS. {items} (Computed internally; see Cost Element 7.)/LCC SC(7)

NAPD(L)

The number of SE items of SERD item number L to be purchased for the depot. {items} (Computed internally; see Cost Element 7.)/LCC SC(7)

NAPH(L)

The total number of SE items of SERD item number L to be purchased. This is the sum of NAPB(L,NS) for all bases NS, plus NAPD(L) for the depot. {items} (Computed internally; see Cost Element 7.)/LCC SC(7)

NCIS(I)

The number of bases where SRUs are stocked to support base-level repair of LRUs of type I. {items} (Computed internally; see Cost Element 10)/LCC SC(10)

NEXF

Control variable for whether expediting is to be employed by the Sparing Routine. Setting NEXF=0 causes expediting factor EXF to be calculated as in the discussion of Sparing Routine inputs. Setting NEXF=1 causes EXF=1.0, the default value for no expediting. {zero or one} (User's control)/EBOS calling procedure for AVAIL

NHM(NS)

Index representing the type of maintenance bench set to be used at base NS. If no maintenance bench set is to be used at base NS, then NHM(NS)=0 is input. Otherwise, NHM(NS) may take a value from one to six. The user specifies which of these six values designate that special AFSATCOM support equipment is also purchased for base NS; for the remainder (if any), special AFSATCOM support equipment is not also purchased for base NS when that type maintenance bench set is purchased for base NS. {index}/LCC SC(3)

NIS(I)

The number of bases where LRUs of type I are used. {items} (Computed internally; see Cost Element 10)/LCC SC(10)

NLRU(I)

Indicator (or flag) variable; NLRU(I)=1 if LRU of type I is utilized at some base in the current AFSATCOM LCC Model run (implying that this LRU type is a new item in Air Force inventory as a result of AFSATCOM acquisition), NLRU(I)=0 otherwise. {0 or 1 indicator} {items} (Computed internally; see Cost Element 10.)/LCC SC(10)

NMT(NS)

The number of men trained for base level maintenance work at base NS. {men} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

NMTB

The number of men trained for base level maintenance work. {men} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

NMTD

The number of men trained for depot level maintenance work. {men} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

NPERB(NS)

The fraction utilization of a (hypothetical) one-man repair shop at base NS, as required by AFSATCOM. Thus NPERB(NS)<1 signifies that at the base NS repair shop AFSATCOM requires less than full-time utilization of one man. If NPERB(NS)>1 then one man will not be sufficient. {decimal fraction} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

NPERD

The fraction utilization of a (hypothetical) one-man repair shop at the depot, as required by AFSATCOM. Thus NPERD<1 signifies that at the depot repair shop AFSATCOM requires less than full-time utilization of one man. If NPERD>1 then one man will not be sufficient. {decimal fraction} (Computed internally; see Cost Element 8.)/LCC SC(8), SC(9)

NRT

Fraction of LRUs normally base-repairable which are sent to the depot due to the severity of their damage ("basket cases"). {decimal fraction} (AF)/LCC SC(4), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

NRTS(I)

Fraction of removals of LRU of type I expected to be returned to the depot *for repair*. {decimal fraction} (Based upon the results of an ORLA Routine [3]; see also Exhibit 3.)/LCC SC(4), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2); AVAIL

NRTS(J)

Fraction of removals of SRU of type J expected to be returned to the depot for repair. {decimal fraction} (Based upon the results of an ORLA Routine [3] run at the SRU level.)/LCC SC(5)

NRTS1(M)

A normalization of NRTS(I) for category M containing LRU type I, to convert NRTS(I) into a zero-one variable. {zero or one} (Computed internally; see Cost Element 8.)/LCC SC(8)

NS

Index representing specific bases. {index}/CONSO; LCC; EBOS calling procedure; AVAIL

NTS(K)

The total number of terminals of type K to be purchased. {items} (Computed internally; see Cost Element 1.)/LCC SC(1)

OST(LO)

Average order and one-way shipping time from the depot to a base at location LO. {mo.} (AF)/EBOS calling procedure for LCC SC(2) and for AVAIL

PA(I)

The number of new "P"-coded assemblies (SRUs) which, as a result of AFSATCOM acquisition, would be added to the Air Force inventory system to support repair of LRUs of type I if such LRU type is to be repaired. {items} (Contractor)/LCC SC(10)

PAL

Student pay and allowances for average grade trained during initial training. {$/man/week} (AF)/LCC SC(8)

PC

Output variable for Subroutine EBOS: Probability of backordering, i.e., of needing one or more spares for replacement after inventory has been depleted (hence, probability of at least one NORS terminal), at a random point in time or per month, for a given situation of interest (LRUs of type I, at base NS or at the depot). {decimal fraction or decimal fraction/mo.} (Computed internally; see discussions of Sparing Routine steady-state probabilities and Sparing Routine outputs, including Exhibit 4.)/EBOS

PCB(I,NS)

Probability of backordering, i.e., of needing one or more spares for replacement after inventory has been depleted, at a random point in time, for LRU type I at base NS. {decimal fraction} (Computed by Sparing Routine as PC for the following situation of interest: LRUs of type I, at base NS.)/AVAIL via EBOS

PCC(I,NS)

Probability of backordering, i.e., of needing one or more spares for replacement after inventory has been depleted, at a random point in time, for LRU type I, at the CIMF which services base NS; defined only for centralized maintenance posture, and for bases which do not have their own repair facility. {decimal fraction} (Computed internally by the Availability Routine.)/AVAIL via EBOS

PCD(I)

Probability of backordering, i.e., of needing one or more spares for replacement after inventory has been depleted, at a random point in time, for LRU type I, at the depot. {decimal fraction} (Computed by Sparing Routine as PC for the following situation of interest: LRUs of type I, at the depot.)/AVAIL via EBOS

PIUP

Operational service life of the system (Program Inventory Usage Period). {yrs.} (AF)/LCC SC(3), SC(4), SC(5), SC(6), SC(7), SC(9), SC(10), SC(11)

PS(LO)

Packing and shipping costs as a function of base location LO. {$/lb.} (AF)/LCC SC(4)

PWR(LO)

Ratio of packaged weight to unpackaged weight of LRUs, SRUs, which fail at base location LO. {decimal factor} (AF)/LCC SC(4)

QLB1(I,NS)

The quantity of LRUs of type I which are installed in all of the terminals at base NS. {items} (Computed internally; see Appendix B.)/LCC

QLRU1(I)

The quantity of LRUs of type I which are installed in all of the terminals at all of the bases. {items} (Computed internally; see Appendix B.)/LCC

QLRU2(I)

The quantity of LRUs of type I which are acquired for initial sparing at all sites (bases plus depot). {items} (Computed internally; see Appendix B.)/LCC

QLRU3(I)

The quantity of LRUs of type I which are installed in all of the maintenance bench sets at all of the bases which have maintenance bench sets. {items} (Computed internally; see Appendix B.)/LCC

QPA(I,K)

The quantity of LRUs of type I installed in a terminal of type K. {items/item} (AF; configuration of LRUs in terminals is controllable by the user via this matrix.)/LCC SC(1), SC(4), SC(5), SC(6), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

QS

Output variable for Subroutine EBOS: Quantity of spares to be acquired for inventory, for a given situation of interest (LRUs of type I, at base NS or at the depot). {items} (Computed internally; see discussion of Sparing Routine outputs, including Exhibit 4.)/EBOS

RIP(I)

Probability of "in-place" maintenance, given that an LRU of type I undergoes some maintenance action. Thus (1-RIP(I)) is the fraction of maintenance actions on LRUs of type I that require removal of the LRU. {decimal fraction} (Contractor)/LCC SC(4), SC(5), SC(6), SC(7), SC(8), SC(9); EBOS calling procedure for LCC SC(2)

RM(I)

Average repair materials cost per failure of an LRU of type I, when this LRU type does <u>not</u> further subdivide into SRUs. {$/item} (Contractor)/LCC SC(5)

RMH(I)

Average number of man-hours required to remove and replace an LRU of type I. {man-hrs./item} (Contractor)/LCC SC(6), SC(8), SC(9); AVAIL

RT(I)

Average number of man-hours required to repair an LRU of type I at base or depot, including time to diagnose, attempt to repair. {man-hrs./item} (Contractor)/LCC SC(4), SC(7), SC(8), SC(9); EBOS calling procedure; AVAIL

RTF(I,NS)

Expected round trip packing and shipping cost for an LRU of type I dispatched from base NS, given that the LRU has been removed for repairs. {$/item} (Computed internally; see Cost Element 4.)/LCC SC(4)

RTFC(I,NS)

Expected round trip packing and shipping cost for an LRU of type I sent to CIMF base NS for repairs, when using centralized maintenance posture. {$/item} (Computed internally; see Cost Element 4.)/LCC SC(4)

RTS(I)

Fraction of removals of LRU of type I expected to be repaired at the base. {decimal fraction} (Based upon the results of an ORLA Routine [3]; see also Exhibit 3.)/ LCC SC(4), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for LCC SC(2); AVAIL

RTS(J)

Fraction of removals of SRU of type J expected to be repaired at the base. {decimal fraction} (Based upon the results of an ORLA Routine [3] run at the SRU level.)/LCC SC(5)

RTS1(M)

A normalization of RTS(I) for category M containing LRU type I, to convert RTS(I) into a zero-one variable. {zero or one} (Computed internally; see Cost Element 8.)/LCC SC(8)

SA

Annual supply inventory management cost per base. {$/item/yr.} (AF)/LCC SC(10)

SB(I,NS)

The number of spares of LRU type I to be acquired for inventory at base NS. {items} (Computed by Sparing Routine as QS for the following situation of interest: LRUs of type I, at base NS.)/LCC SC(2) via EBOS

SC(N)

Designator for Cost Element N, where N is some integer from 1 to 11. These are the basic subcosts of the AFSATCOM LCC Model, and are computed over the operational service life of the system. {$} (Computed by LCC Routine.)/LCC

SD(I)

The number of spares of LRU type I to be acquired for inventory at the depot. {items} (Computed by Sparing Routine as QS for the following situation of interest: LRUs of type I, at base NS.)/LCC SC(2) via EBOS

SMH(I)

Average number of man-hours required to perform scheduled maintenance (including preventive maintenance, preflight, postflight, periodic inspections of the subsystems, and any remove and replace time) on an LRU of type I. {man-hrs./item} (Contractor)/LCC SC(6)

SMI(I)

Average scheduled maintenance interval for an LRU of type I. {mos./item} (Contractor)/LCC SC(6)

TCMB

Average per-man cost of a base level maintenance course, including instruction and training materials. {$/man} (AF)/LCC SC(9)

TCMD

Average per-man cost of a depot level maintenance course, including instruction and training materials. {$/man} (AF)/LCC SC(9)

TCMW

Average cost of initial contractor-provided training for base and depot maintenance personnel, including instruction and training materials. {$/man/week} (Contractor & AF)/LCC SC(8)

TDAP(L)

The number of technical data pages (or page negatives) required to support SE item (items) of SERD item number L. {pages} (Contractor)/LCC SC(11)

TDLP(I)

The number of technical data pages (or page negatives) required to support an LRU of type I. {pages} (Contractor)/LCC SC(11)

TDP

Technical document reproduction cost (per thousand copies). {$/page} (AF)/LCC SC(11)

TDSP

The number of technical data pages (or page negatives) required to support the AFSATCOM system as a whole. {pages} (Contractor)/LCC SC(11)

TDTP(K)

The number of technical data pages (or page negatives) required to support a terminal of type K. {pages} (Contractor)/LCC SC(11)

TDU

Technical document annual upkeep cost. {$/page/yr} (AF)/LCC SC(11)

TE

Cost of required training equipment. {$} (Contractor & AF)/LCC SC(8)

TOPI

Cost of initial training of organizational-level maintenance and operator/specialist personnel. {$} (AF)/LCC SC(8)

TOPR

Annual cost of replenishment training of organizational-level maintenance and operator/specialist personnel. {$/yr.} (AF)/LCC SC(9)

TRANB(IBS)

Transportation time associated with on-base delivery of a replacement LRU from base supply location IBS to the line. {hrs.} (AF)/EBOS calling procedure; AVAIL

TRANC

Transportation time associated with shipment of a replacement LRU from a CIMF to a base serviced by that CIMF, via an expedited priority, when using centralized maintenance posture. {hrs.} (AF)/EBOS calling procedure; AVAIL

TRAND(LO)

Transportation time associated with shipment of a replacement LRU from the depot to a base with base location LO, via an expedited priority. {hrs.} (AF)/EBOS calling procedure; AVAIL

TRANS(I,NS)

Mean replacement time for acquiring an LRU of type I at base NS, given that base inventory of that LRU type is depleted. {hrs.} (Computed internally by the Availability Routine; see also Appendix C.)/AVAIL

TRB(NS)

The additional fraction of men at base NS which must be trained annually to fill maintenance personnel vacancies. {decimal fraction/yr.} (AF)/LCC SC(9)

TRD

The additional fraction of men at the depot which must be trained annually to fill maintenance personnel vacancies. {decimal fraction/yr.} (AF)/LCC SC(9)

TW(M)

Average time required to train a man to repair any LRU type in category M. {weeks} (Contractor)/LCC SC(8)

U(X)

Unit step function for strictly positive X. {zero or one}/LCC

$$U(X) = 1 \text{ if } X > 0$$
$$= 0 \text{ if } X \leq 0$$

UC(I)

The validated unit cost for an LRU of type I, that is, the price exhibited for the initial provisioning of the item. {$/item} (Contractor & AF)/LCC SC(1), SC(2), SC(3), SC(5)

WOR

Fraction of failures, of normally repairable LRUs, which can no longer be repaired (wearout fraction). {decimal fraction} (AF)/LCC SC(4), SC(5), SC(7), SC(8), SC(9), SC(10); EBOS calling procedure for SC(2); AVAIL

WT(I)

Net weight of an LRU of type I. {lbs./item} (Contractor)/LCC SC(4)

XF(I,K)

Expected number of removals per month of LRU type I in terminal type K. {items/mo.} (Computed internally; see Cost Element 4.)/LCC SC(4), SC(5), SC(6)

XFB(I,NS)

Expected number of removals per month of LRU type I at base NS. {items/mo.} (Computed internally; see Cost Element 4.)/LCC SC(4); EBOS calling procedure for LCC SC(2) and for AVAIL

XFBN(I,NS)

Composite expected number of removals per month of LRU type I among shipments from bases without repair facilities to a given CIMF base NS, when using centralized maintenance posture. {items/mo.} (Computed internally; see Cost Element 4.)/LCC SC(4); EBOS calling procedure for LCC SC(2) and for AVAIL

XFL(I)

Total expected number of removals (failures) of LRU type I, in all terminals at all bases, over the life cycle. {items} (Computed internally; see Cost Element 4.)/LCC output only

REFERENCES

[1] Logistics Support Cost Model, User's Handbook, Headquarters AFLC/AQMLE, June 1975.

[2] Military Standard Work Breakdown Structures for Defense Materiel Items, MIL-STD-881, 1 November 1968.

[3] Optimum Repair-Level Analysis (ORLA), Air Force Manual AFLCM/AFSCM 800-4, 25 June 1971.

[4] AFSATCOM ORLA by Site (SITEORLA), unpublished draft by J. J. Fabish, Sacramento ALC/MMER, 10 June 1974.

[5] D. Gross and C. M. Harris, Fundamentals of Queueing Theory, J. Wiley & Sons, Inc., New York, Toronto, 1974.

[6] C. C. Sherbrooke, "An Evaluator for the Number of Operationally Ready Aircraft in a Multilevel Supply System," Operations Research, Vol. 19, pp. 618-635 (1971); published previously as MINE: Multi-Indenture NORS Evaluator, The Rand Corporation, RM-5826-PR, December 1968.

[7] Stock Control at Bases, Chapter 11 of Air Force Manual AFM 67-1, Vol. II, Part One, 4 March 1974.

[8] S. M. Ross, Applied Probability Models with Optimization Applications, Holden-Day, Inc., San Francisco, 1970.

[9] R. E. Barlow and F. Proschan, "Availability Theory for Multicomponent Systems," report ORC 72-8, Operations Research Center, University of California, Berkeley, April 1972.